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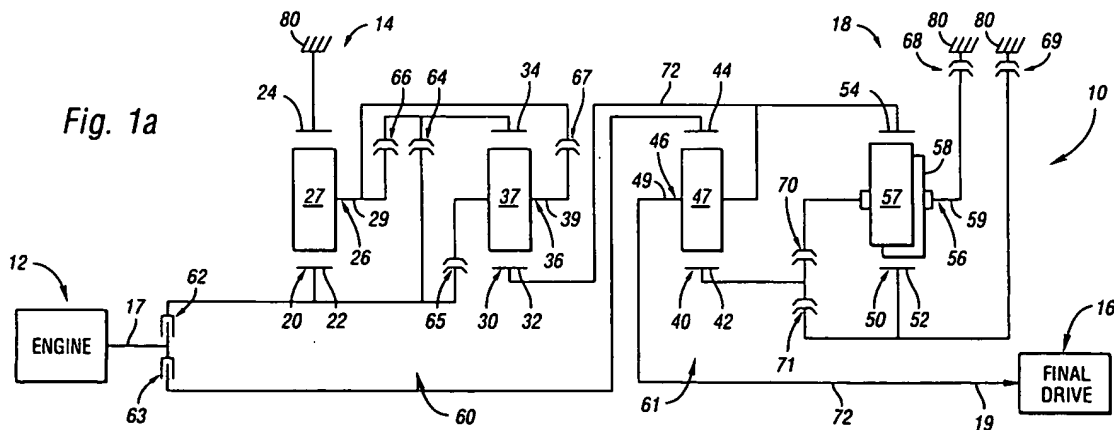
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(54) **Family of six-speed dual-clutch transmissions having a stationary planetary member and two brakes**

(57) The family of transmissions has a plurality of members that can be utilized in powertrains to provide at least six forward speed ratios and one reverse speed ratio. The transmission family members include four planetary gear sets (20,30,40,50), two input clutches (62,63), eight torque transmitting mechanisms, two fixed interconnections (72), and one grounded planetary gear member (52). The invention provides low content multi-speed dual-clutch transmission mechanisms wherein the two input clutches (62,63) alternately connect the engine to realize odd and even number speed

ratio ranges. The eight torque transmitting mechanisms provide connections between various gear members, the fixed interconnections (72), the input clutches (62,63), the output shaft (19), and the transmission housing (80), and are operated in combinations of three to establish at least six forward speed ratios and at least one reverse speed ratio. One of the torque transmitting mechanisms may be eliminated to provide at least five forward speed ratios and at least one reverse speed ratio. Also, two of the torque transmitting mechanisms may function as one of the input clutches to reduce content.



Description

TECHNICAL FIELD

[0001] The present invention relates to a family of power transmissions having two input clutches which selectively connect an input shaft to first and second pairs of planetary gear sets to provide at least six forward speed ratios and one reverse speed ratio.

BACKGROUND OF THE INVENTION

[0002] Passenger vehicles include a powertrain that is comprised of an engine, multi-speed transmission, and a differential or final drive. The multi-speed transmission increases the overall operating range of the vehicle by permitting the engine to operate through its torque range a number of times.

[0003] A primary focus of transmission and engine design work is in the area of increasing vehicle fuel efficiency. Manual transmissions typically provide improved vehicle fuel economy over automatic transmissions because automatic transmissions use a torque converter for vehicle launch and multiple plate hydraulically-applied clutches for gear engagement. Clutches of this type, left unengaged or idling, impose a parasitic drag torque on a drive line due to the viscous shearing action which exists between the plates and discs rotating at different speeds relative to one another. This drag torque adversely affects fuel economy for automatic transmissions. Also, the hydraulic pump that generates the pressure needed for operating the above-described clutches further reduces fuel efficiency associated with automatic transmissions. Manual transmissions eliminate these problems.

[0004] While manual transmissions are not subject to the above described fuel efficiency related problems, manual transmissions typically provide poor shift quality because a significant torque interruption is required during each gear shift as the engine is disengaged from the transmission by the clutch to allow shafts rotating at different speeds to be synchronized.

[0005] So called "automated manual" transmissions provide electronic shifting in a manual transmission configuration which, in certain circumstances, improves fuel efficiency by eliminating the parasitic losses associated with the torque converter and hydraulic pump needed for clutching. Like manual transmissions, a drawback of automated manual transmissions is that the shift quality is not as high as an automatic transmission because of the torque interruption during shifting.

[0006] So called "dual-clutch automatic" transmissions also eliminate the torque converter and replace hydraulic clutches with synchronizers but they go further to provide gear shift quality which is superior to the automated manual transmission and similar to the conventional automatic transmission, which makes them quite attractive. However, most known dual-clutch automatic

transmissions include a lay shaft or countershaft gear arrangement, and have not been widely applied in vehicles because of their complexity, size and cost. For example, a dual clutch lay shaft transmission could require eight sets of gears, two input/shift clutches and seven synchronizers/dog clutches to provide six forward speed ratios and a reverse speed ratio. An example of a dual-clutch automatic transmission is described in U. S. Patent Number 5,385,064, which is hereby incorporated by reference.

SUMMARY OF THE INVENTION

[0007] The invention provides a low content multi-speed dual-clutch transmission family utilizing planetary gear sets rather than lay shaft gear arrangements. In particular, the invention includes four planetary gear sets, two input/shift clutches, and eight selectable torque transmitting mechanisms to provide at least six forward speed ratios and a reverse speed ratio.

[0008] According to one aspect of the invention, the family of transmissions has four planetary gear sets, each of which includes a first, second and third member, which members may comprise a sun gear, ring gear, or a planet carrier assembly member.

[0009] In referring to the first, second, third and fourth gear sets in this description and in the claims, these sets may be counted "first" to "fourth" in any order in the drawings (i.e. left-to-right, right-to-left, etc.).

[0010] In another aspect of the present invention, each of the planetary gear sets may be of the single pinion type or of the double pinion type.

[0011] In yet another aspect of the present invention, the first member of the first planetary gear set is continuously connected with a stationary member (transmission housing).

[0012] In yet another aspect of the present invention, the first member of the second planetary gear set is continuously connected with the first member of the third planetary gear set and the output shaft through a first interconnecting member.

[0013] In yet another aspect of the present invention, a member of the third planetary gear set is continuously connected with the first member of the fourth planetary gear set through a second interconnecting member.

[0014] In yet another aspect of the present invention, in some family members, a member of the first planetary gear set is continuously connected with a member of the second planetary gear set through a third interconnecting member.

[0015] In accordance with a further aspect of the invention, a first input clutch selectively connects the input shaft with a member of the first or second planetary gear set either directly or through other torque transmitting mechanisms.

[0016] In accordance with another aspect of the present invention, a second input clutch selectively connects the input shaft with the second or third member of

the third planetary gear set.

[0017] In another aspect of the invention, first, second, third and fourth torque transmitting mechanisms, such as synchronizers, selectively connect members of the first and second planetary gear sets with other members of the first and second planetary gear sets, or with the first input clutch.

[0018] In still a further aspect of the invention, fifth and sixth torque transmitting mechanisms, such as synchronizers, selectively connect members of the third planetary gear set with members of the fourth planetary gear set.

[0019] In still another aspect of the invention, seventh and eighth torque transmitting mechanisms, such as braking synchronizers, selectively connect members of the fourth planetary gear set with the stationary member.

[0020] In accordance with a further aspect of the invention, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of at least three to provide at least six forward speed ratios and a reverse speed ratio.

[0021] In accordance with a further aspect of the invention, the first input clutch is applied for odd number speed ranges, and the second input clutch is applied for even number speed ranges, or vice versa.

[0022] In another aspect of the invention, the first input clutch and the second input clutch are interchanged (i.e. alternately engaged) to shift from odd number speed range to even number speed range, or vice versa.

[0023] In accordance with a further aspect of the invention, each selected torque transmitting mechanism for a new speed ratio is engaged prior to shifting of the input clutches to achieve shifts without torque interruptions.

[0024] In accordance with a further aspect of the invention, at least one pair of synchronizers is executed as a double synchronizer to reduce cost and package size.

[0025] In accordance with a further aspect of the invention, the first input clutch can be eliminated and the first and second torque transmitting mechanisms can be used as input clutches to further reduce content.

[0026] In accordance with a further aspect of the invention, at least one of the torque transmitting mechanisms can be eliminated to realize five forward speed ratios and a reverse speed ratio.

[0027] The above objects, features, advantages, and other objects, features, and advantages of the present invention are readily apparent from the following detailed description of the best modes for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] FIGURE 1a is a schematic representation of a powertrain including a planetary transmission incorporating a family member of the present invention;

[0029] FIGURE 1b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 1a;

[0030] FIGURE 2a is a schematic representation of a powertrain having a planetary transmission incorporating another family member of the present invention;

[0031] FIGURE 2b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 2a;

[0032] FIGURE 3a is a schematic representation of a powertrain having a planetary transmission incorporating another family member of the present invention;

[0033] FIGURE 3b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 3a;

[0034] FIGURE 4a is a schematic representation of a powertrain having a planetary transmission incorporating another family member of the present invention;

[0035] FIGURE 4b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 4a;

[0036] FIGURE 5a is a schematic representation of a powertrain having a planetary transmission incorporating another family member of the present invention;

[0037] FIGURE 5b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 5a;

[0038] FIGURE 6a is a schematic representation of a powertrain having a planetary transmission incorporating another family member of the present invention;

[0039] FIGURE 6b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 6a;

[0040] FIGURE 7a is a schematic representation of a powertrain having a planetary transmission incorporating another family member of the present invention;

[0041] FIGURE 7b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 7a;

[0042] FIGURE 8a is a schematic representation of a powertrain having a planetary transmission incorporating another family member of the present invention;

[0043] FIGURE 8b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 8a;

[0044] FIGURE 9a is a schematic representation of a powertrain having a planetary transmission incorporating another family member of the present invention;

[0045] FIGURE 9b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 9a;

[0046] FIGURE 10a is a schematic representation of a powertrain having a planetary transmission incorporating another family member of the present invention;

[0047] FIGURE 10b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 10a;

[0048] FIGURE 11 a is a schematic representation of

a powertrain having a planetary transmission incorporating another family member of the present invention;
[0049] FIGURE 11b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 11a;

[0050] FIGURE 12a is a schematic representation of a powertrain having a planetary transmission incorporating another family member of the present invention;
[0051] FIGURE 12b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 12a;

[0052] FIGURE 13a is a schematic representation of a powertrain having a planetary transmission incorporating another family member of the present invention; and

[0053] FIGURE 13b is a truth table and chart depicting some of the operating characteristics of the powertrain shown in Figure 13a.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0054] Referring to the drawings, wherein like characters represent the same or corresponding parts throughout the several views, there is shown in Figure 1a a powertrain 10 having a conventional engine 12, a planetary transmission 14, and a conventional final drive mechanism 16.

[0055] The planetary transmission 14 includes an input shaft 17 continuously connected with the engine 12, a planetary gear arrangement 18, and an output shaft 19 continuously connected with the final drive mechanism 16. The planetary gear arrangement 18 includes four planetary gear sets 20, 30, 40 and 50.

[0056] The planetary gear set 20 includes a sun gear member 22, a ring gear member 24, and a planet carrier assembly member 26. The planet carrier assembly member 26 includes a plurality of pinion gears 27 rotatably mounted on a carrier member 29 and disposed in meshing relationship with both the sun gear member 22 and the ring gear member 24.

[0057] The planetary gear set 30 includes a sun gear member 32, a ring gear member 34, and a planet carrier assembly member 36. The planet carrier assembly member 36 includes a plurality of pinion gears 37 rotatably mounted on a carrier member 39 and disposed in meshing relationship with both the sun gear member 32 and the ring gear member 34.

[0058] The planetary gear set 40 includes a sun gear member 42, a ring gear member 44, and a planet carrier assembly member 46. The planet carrier assembly member 46 includes a plurality of pinion gears 47 rotatably mounted on a carrier member 49 and disposed in meshing relationship with both the sun gear member 42 and the ring gear member 44.

[0059] The planetary gear set 50 includes a sun gear member 52, a ring gear member 54, and a planet carrier assembly member 56. The planet carrier assembly

member 56 includes a plurality of intermeshing pinion gears 57, 58 rotatably mounted on a carrier member 59 and disposed in meshing relationship with the ring gear member 54 and the sun gear member 52, respectively.

[0060] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 20, 30, 40 and 50 are divided into first and second transmission subsets 60, 61 which are alternatively engaged to provide odd number and even number speed ranges, respectively. Transmission subset 60 includes planetary gear sets 20 and 30, and transmission subset 61 includes planetary gear sets 40 and 50. The output shaft 19 is continuously connected with members of both subsets 60 and 61.

[0061] As mentioned above, the first and second input clutches 62, 63 are alternatively engaged for transmitting power from the input shaft 17 to transmission subset 60 or transmission subset 61. The first and second input clutches 62, 63 are controlled electronically, and the disengaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speeds are preselected within the transmission subsets 60, 61 prior to engaging the respective input clutches 62, 63. The preselection is achieved by means of electronically controlled synchronizers. As shown, the planetary gear arrangement includes eight torque transmitting mechanisms 64, 65, 66, 67, 68, 69, 70 and 71. The torque transmitting mechanisms 68 and 69 comprise braking synchronizers, and the torque transmitting mechanisms 64, 65, 66, 67, 70 and 71 comprise rotating synchronizers.

[0062] The braking synchronizers and rotating synchronizers are referenced in the claims as follows: first, second, third and fourth torque transmitting mechanisms 64, 65, 66, 67; fifth and sixth torque transmitting mechanisms 70, 71; and seventh and eighth torque transmitting mechanisms 68, 69. Other family members are similarly referenced in the claims (i.e. rotating synchronizers generally in order of planetary gear sets from left to right in Figures, and braking synchronizers generally in order of planetary gear sets from left to right in Figures).

[0063] By way of example, synchronizers which may be implemented as the rotating and/or braking synchronizers referenced herein are shown in the following patents, each of which are incorporated by reference in their entirety: U.S. Patent Numbers 5,651,435; 5,975,263; 5,560,461; 5,641,045; 5,497,867; 6,354,416.

[0064] Accordingly, the input shaft 17 is alternately connected with the first and second transmission subsets 60, 61 (i.e. through the clutch 62 to the sun gear member 22 and through the clutch 63 to the ring gear

member 44). The ring gear member 24 is continuously connected with the transmission housing 80. The planet carrier assembly member 46 is continuously connected with the sun gear member 32, the output shaft 19 and the ring gear member 54 through the interconnecting member 72.

[0065] The sun gear member 22 is selectively connectable with the ring gear member 34 through the synchronizer 64. The sun gear member 22 is selectively connectable with the planet carrier assembly member 36 through the synchronizer 65. The planet carrier assembly member 26 is selectively connectable with the ring gear member 34 through the synchronizer 66. The planet carrier assembly member 26 is selectively connectable with the planet carrier assembly member 36 through the synchronizer 67. The planet carrier assembly member 56 is selectively connectable with the transmission housing 80 through the braking synchronizer 68. The sun gear member 52 is selectively connectable with the transmission housing 80 through the braking synchronizer 69. The sun gear member 42 is selectively connectable with the planet carrier assembly member 56 through the synchronizer 70. The sun gear member 42 is selectively connectable with the sun gear member 52 through the synchronizer 71.

[0066] As shown in Figure 1b, and in particular the truth table disclosed therein, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of three to provide six forward speed ratios and a reverse speed ratio.

[0067] The reverse speed ratio is established with the engagement of the input clutch 62 and the synchronizers 64, 67. The input clutch 62 connects the sun gear member 22 to the input shaft 17. The synchronizer 64 connects the sun gear member 22 to the ring gear member 34. The synchronizer 67 connects the planet carrier assembly member 26 to the planet carrier assembly member 36. The sun gear member 22 and the ring gear member 34 rotate at the same speed as the input shaft 17. The planet carrier assembly member 26 rotates at the same speed as the planet carrier assembly member 36. The ring gear member 24 does not rotate. The planet carrier assembly member 26 rotates at a speed determined from the speed of the sun gear member 22 and the ring gear/sun gear tooth ratio of the planetary gear set 20. The sun gear member 32 and the planet carrier assembly member 46 rotate at the same speed as the output shaft 19. The sun gear member 32, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 34, the speed of the planet carrier assembly member 36 and the ring gear/sun gear tooth ratio of the planetary gear set 30. The numerical value of the reverse speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 20, 30.

[0068] The first forward speed ratio is established with the engagement of the input clutch 62 and the synchronizers 66, 67. The input clutch 62 connects the sun gear

member 22 to the input shaft 17. The synchronizer 66 connects the planet carrier assembly member 26 to the ring gear member 34. The synchronizer 67 connects the planet carrier assembly member 26 to the planet carrier assembly member 36. The sun gear member 22 rotates at the same speed as the input shaft 17. The planet carrier assembly member 26, the planetary gear set 30 and the planet carrier assembly member 46 rotate at the same speed as the output shaft 19. The ring gear member 24 does not rotate. The planet carrier assembly member 26, and therefore the output shaft 19, rotates at a speed determined from the speed of the sun gear member 22 and the ring gear/sun gear tooth ratio of the planetary gear set 20. The numerical value of the first forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 20.

[0069] The second forward speed ratio is established with the engagement of the input clutch 63, the braking synchronizer 68 and the synchronizer 70. The input clutch 63 connects the ring gear member 44 to the input shaft 17. The braking synchronizer 68 connects the planet carrier assembly member 56 to the transmission housing 80. The synchronizer 70 connects the sun gear member 42 to the planet carrier assembly member 56. The sun gear member 42 and the planet carrier assembly member 56 do not rotate. The planet carrier assembly member 46 and the ring gear member 54 rotate at the same speed as the output shaft 19. The ring gear member 44 rotates at the same speed as the input shaft 17. The planet carrier assembly member 46, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 44 and the ring gear/sun gear tooth ratio of the planetary gear set 40. The numerical value of the second forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 40.

[0070] The third forward speed ratio is established with the engagement of the input clutch 62 and the synchronizers 64, 65. In this configuration, the input shaft 17 is directly connected to the output shaft 19. The numerical value of the third forward speed ratio is 1.

[0071] The fourth forward speed ratio is established with the engagement of the input clutch 63, the braking synchronizer 69 and the synchronizer 70. The input clutch 63 connects the ring gear member 44 to the input shaft 17. The braking synchronizer 69 connects the sun gear member 52 to the transmission housing 80. The synchronizer 70 connects the sun gear member 42 to the planet carrier assembly member 56. The sun gear member 42 rotates at the same speed as the planet carrier assembly member 56. The planet carrier assembly member 46 and the ring gear member 54 rotate at the same speed as the output shaft 19. The ring gear member 44 rotates at the same speed as the input shaft 17. The planet carrier assembly member 46, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 44, the speed of the sun gear member 42 and the ring gear/sun gear tooth

ratio of the planetary gear set 40. The sun gear member 52 does not rotate. The planet carrier assembly member 56 rotates at a speed determined from the speed of the ring gear member 54 and the ring gear/sun gear tooth ratio of the planetary gear set 50. The numerical value of the fourth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 40, 50.

[0072] The fifth forward speed ratio is established with the engagement of the input clutch 62 and the synchronizers 65, 66. The input clutch 62 connects the sun gear member 22 to the input shaft 17. The synchronizer 65 connects the sun gear member 22 to the planet carrier assembly member 36. The synchronizer 66 connects the planet carrier assembly member 26 to the ring gear member 34. The sun gear member 22 and the planet carrier assembly member 36 rotate at the same speed as the input shaft 17. The planet carrier assembly member 26 rotates at the same speed as the ring gear member 34. The ring gear member 24 does not rotate. The planet carrier assembly member 26 rotates at a speed determined from the speed of the sun gear member 22 and the ring gear/sun gear tooth ratio of the planetary gear set 20. The sun gear member 32 and the planet carrier assembly member 46 rotate at the same speed as the output shaft 19. The sun gear member 32, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 34, the speed of the planet carrier assembly member 36 and the ring gear/sun gear tooth ratio of the planetary gear set 30. The numerical value of the fifth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 20, 30.

[0073] The sixth forward speed ratio is established with the engagement of the input clutch 63, the braking synchronizer 68 and the synchronizer 71. The input clutch 63 connects the ring gear member 44 to the input shaft 17. The braking synchronizer 68 connects the planet carrier assembly member 56 to the transmission housing 80. The synchronizer 71 connects the sun gear member 42 to the sun gear member 52. The sun gear member 42 rotates at the same speed as the sun gear member 52. The planet carrier assembly member 46 and the ring gear member 54 rotate at the same speed as the output shaft 19. The ring gear member 44 rotates at the same speed as the input shaft 17. The planet carrier assembly member 46, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 44, the speed of the sun gear member 42 and the ring gear/sun gear tooth ratio of the planetary gear set 40. The planet carrier assembly member 56 does not rotate. The ring gear member 54 rotates at a speed determined from the speed of the sun gear member 52 and the ring gear/sun gear tooth ratio of the planetary gear set 50. The numerical value of the sixth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 40, 50.

[0074] As set forth above, the engagement schedule

for the torque transmitting mechanisms is shown in the truth table of Figure 1b. This truth table also provides an example of speed ratios that are available utilizing the ring gear/sun gear tooth ratios given by way of example in Figure 1b. The R1/S1 value is the tooth ratio of the planetary gear set 20; the R2/S2 value is the tooth ratio of the planetary gear set 30; the R3/S3 value is the tooth ratio of the planetary gear set 40; and the R4/S4 value is the tooth ratio of the planetary gear set 50. Also, the chart of Figure 1b describes the ratio steps that are attained utilizing the sample of tooth ratios given. For example, the step ratio between first and second forward speed ratios is 1.77, while the step ratio between the reverse and first forward ratio is -0.78.

[0075] Figure 2a shows a powertrain 110 having a conventional engine 12, a planetary transmission 114, and a conventional final drive mechanism 16. The planetary transmission 114 includes an input shaft 17 connected with the engine 12, a planetary gear arrangement 118, and an output shaft 19 connected with the final drive mechanism 16. The planetary gear arrangement 118 includes four planetary gear sets 120, 130, 140 and 150.

[0076] The planetary gear set 120 includes a sun gear member 122, a ring gear member 124, and a planet carrier assembly member 126. The planet carrier assembly member 126 includes a plurality of pinion gears 127 rotatably mounted on a carrier member 129 and disposed in meshing relationship with both the sun gear member 122 and the ring gear member 124.

[0077] The planetary gear set 130 includes a sun gear member 132, a ring gear member 134, and a planet carrier assembly member 136. The planet carrier assembly member 136 includes a plurality of pinion gears 137 rotatably mounted on a carrier member 139 and disposed in meshing relationship with both the sun gear member 132 and the ring gear member 134.

[0078] The planetary gear set 140 includes a sun gear member 142, a ring gear member 144, and a planet carrier assembly member 146. The planet carrier assembly member 146 includes a plurality of pinion gears 147 rotatably mounted on a carrier member 149 and disposed in meshing relationship with both the sun gear member 142 and the ring gear member 144.

[0079] The planetary gear set 150 includes a sun gear member 152, a ring gear member 154, and a planet carrier assembly member 156. The planet carrier assembly member 156 includes a plurality of intermeshing pinion gears 157, 158 rotatably mounted on a carrier member 159 and disposed in meshing relationship with the ring gear member 154 and the sun gear member 152, respectively.

[0080] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 120, 130, 140 and 150 are divided into first and second transmission subsets 160, 161 which are alternatively engaged to provide odd number and even number speed ranges, respectively. Transmission subset 160 includes plane-

tary gear sets 120 and 130, and transmission subset 161 includes planetary gear sets 140 and 150. The output shaft 19 is continuously connected with members of both subsets 160 and 161.

[0081] As mentioned above, the first and second input clutches 162, 163 are alternatively engaged for transmitting power from the input shaft 17 to transmission subset 160 or transmission subset 161. The first and second input clutches 162, 163 are controlled electronically, and the disengaged input clutch is gradually engaged while the engaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speeds are preselected within the transmission subsets 160, 161 prior to engaging the respective input clutches 162, 163. The preselection is achieved by means of electronically controlled synchronizers. As shown, the planetary gear arrangement includes eight torque transmitting mechanisms 164, 165, 166, 167, 168, 169, 170 and 171. The torque transmitting mechanisms 168 and 169 comprise braking synchronizers, and the torque transmitting mechanisms 164, 165, 166, 167, 170 and 171 comprise rotating synchronizers.

[0082] Accordingly, the input shaft 17 is alternately connected with the first and second transmission subsets 160, 161 (i.e. through the clutch 162 to the sun gear member 132 and through the clutch 163 to the ring gear member 144). The sun gear member 122 is continuously connected with the transmission housing 180. The ring gear member 124 is continuously connected with the planet carrier assembly member 136 through the interconnecting member 172. The planet carrier assembly member 146 is continuously connected with the ring gear member 134, the output shaft 19 and the ring gear member 154 through the interconnecting member 174.

[0083] The planet carrier assembly member 136 is selectively connectable with the sun gear member 132 through the synchronizer 164. The planet carrier assembly member 126 is selectively connectable with the ring gear member 134 through the synchronizer 165. The planet carrier assembly member 126 is selectively connectable with the sun gear member 132 through the synchronizer 166. The ring gear member 124 is selectively connectable with the planet carrier assembly member 126 through the synchronizer 167. The planet carrier assembly member 156 is selectively connectable with the transmission housing 180 through the braking synchronizer 168. The sun gear member 152 is selectively connectable with the transmission housing 180 through the braking synchronizer 169. The sun gear member 142 is selectively connectable with the planet carrier assembly member 156 through the synchronizer 170. The sun gear member 142 is selectively connectable with the sun gear member 152 through the synchronizer 171.

[0084] As shown in Figure 2b, and in particular the truth table disclosed therein, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of at least two to provide six forward speed ratios and a reverse speed ratio.

[0085] The reverse speed ratio is established with the engagement of the input clutch 162 and the synchronizer 167. The input clutch 162 connects the sun gear member 132 to the input shaft 17. The synchronizer 167 connects the ring gear member 124 to the planet carrier assembly member 126. The planetary gear set 120 and the planet carrier assembly member 136 do not rotate. The sun gear member 132 rotates at the same speed as the input shaft 17. The ring gear member 134 and the planet carrier assembly member 146 rotate at the same speed as the output shaft 19. The ring gear member 134, and therefore the output shaft 19, rotates at a speed determined from the speed of the sun gear member 132 and the ring gear/sun gear tooth ratio of the planetary gear set 130. The numerical value of the reverse speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 130.

[0086] The first forward speed ratio is established with the engagement of the input clutch 162 and the synchronizer 165. The input clutch 162 connects the sun gear member 132 to the input shaft 17. The synchronizer 165 connects the planet carrier assembly member 126 to the ring gear member 134. The sun gear member 122 does not rotate. The planet carrier assembly members 126, 146 and the ring gear member 134 rotate at the same speed as the output shaft 19. The ring gear member 124 rotates at the same speed as the planet carrier assembly member 136. The planet carrier assembly member 126, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 124 and the ring gear/sun gear tooth ratio of the planetary gear set 120. The sun gear member 132 rotates at the same speed as the input shaft 17. The planet carrier assembly member 136 rotates at a speed determined from the speed of the ring gear member 134, the speed of the sun gear member 132 and the ring gear/sun gear tooth ratio of the planetary gear set 130. The numerical value of the first forward speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 120, 130.

[0087] The second forward speed ratio is established with the engagement of the input clutch 163, the braking synchronizer 168 and the synchronizer 170. The input clutch 163 connects the ring gear member 144 to the input shaft 17. The braking synchronizer 168 connects the planet carrier assembly member 156 to the transmission housing 180. The synchronizer 170 connects the sun gear member 142 to the planet carrier assembly member 156. The sun gear member 142 and the planet carrier assembly member 156 do not rotate. The planet carrier assembly member 146 and the ring gear member 154 rotate at the same speed as the output shaft 19. The ring gear member 144 rotates at the same speed

as the input shaft 17. The planet carrier assembly member 146, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 144 and the ring gear/sun gear tooth ratio of the planetary gear set 140. The numerical value of the second forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 140.

[0088] The third forward speed ratio is established with the engagement of the input clutch 162 and the synchronizer 164. In this configuration, the input shaft 17 is directly connected to the output shaft 19. The numerical value of the third forward speed ratio is 1.

[0089] The fourth forward speed ratio is established with the engagement of the input clutch 163, the braking synchronizer 169 and the synchronizer 170. The input clutch 163 connects the ring gear member 144 to the input shaft 17. The braking synchronizer 169 connects the sun gear member 152 to the transmission housing 180. The synchronizer 170 connects the sun gear member 142 to the planet carrier assembly member 156. The sun gear member 142 rotates at the same speed as the planet carrier assembly member 156. The planet carrier assembly member 146 and the ring gear member 154 rotate at the same speed as the output shaft 19. The ring gear member 144 rotates at the same speed as the input shaft 17. The planet carrier assembly member 146, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 144, the speed of the sun gear member 142 and the ring gear/sun gear tooth ratio of the planetary gear set 140. The ring gear member 152 does not rotate. The planet carrier assembly member 156 rotates at a speed determined from the speed of the ring gear member 154 and the ring gear/sun gear tooth ratio of the planetary gear set 150. The numerical value of the fourth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 140, 150.

[0090] The fifth forward speed ratio is established with the engagement of the input clutch 162 and the synchronizer 166. The input clutch 162 connects the sun gear member 132 to the input shaft 17. The synchronizer 166 connects the planet carrier assembly member 126 to the sun gear member 132. The sun gear member 122 does not rotate. The planet carrier assembly member 126 and the sun gear member 132 rotate at the same speed as the input shaft 17. The ring gear member 124 rotates at the same speed as the planet carrier assembly member 136. The ring gear member 124 rotates at a speed determined from the speed of the planet carrier assembly member 126 and the ring gear/sun gear tooth ratio of the planetary gear set 120. The ring gear member 134 and the planet carrier assembly member 146 rotate at the same speed as the output shaft 19. The ring gear member 134, and therefore the output shaft 19, rotates at a speed determined from the speed of the planet carrier assembly member 136, the speed of the sun gear member 132 and the ring gear/sun gear tooth ratio of the planetary gear set 130. The numerical value of the

fifth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 120, 130.

[0091] The sixth forward speed ratio is established with the engagement of the input clutch 163, the braking synchronizer 168 and the synchronizer 171. The input clutch 163 connects the ring gear member 144 to the input shaft 17. The braking synchronizer 168 connects the planet carrier assembly member 156 to the transmission housing 180. The synchronizer 171 connects the sun gear member 142 to the sun gear member 152. The sun gear member 142 rotates at the same speed as the sun gear member 152. The planet carrier assembly member 146 and the ring gear member 154 rotate at the same speed as the output shaft 19. The ring gear member 144 rotates at the same speed as the input shaft 17. The planet carrier assembly member 146, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 144, the speed of the sun gear member 142 and the ring gear/sun gear tooth ratio of the planetary gear set 140. The planet carrier assembly member 156 does not rotate. The ring gear member 154 rotates at a speed determined from the speed of the sun gear member 152 and the ring gear/sun gear tooth ratio of the planetary gear set 150. The numerical value of the sixth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 140, 150.

[0092] As set forth above, the truth table of Figure 2b describes the engagement sequence of the torque transmitting mechanisms utilized to provide a reverse drive ratio and six forward speed ratios. The truth table also provides an example of the ratios that can be attained with the family members shown in Figure 2a utilizing the sample tooth ratios given in Figure 2b. The R1/S1 value is the tooth ratio of the planetary gear set 120; the R2/S2 value is the tooth ratio of the planetary gear set 130; the R3/S3 value is the tooth ratio of the planetary gear set 140; and the R4/S4 value is the tooth ratio of the planetary gear set 150. Also shown in Figure 2b are the ratio steps between single step ratios in the forward direction as well as the reverse to first ratio step. For example, the first to second step ratio is 1.81.

[0093] Turning the Figure 3a, a powertrain 210 having a conventional engine 12, a planetary transmission 214, and conventional final drive mechanism 16 is shown.

[0094] The planetary transmission 214 includes an input shaft 17 continuously connected with the engine 12, a planetary gear arrangement 218, and an output shaft 19 continuously connected with the final drive mechanism 16. The planetary gear arrangement 218 includes four planetary gear sets 220, 230, 240 and 250.

[0095] The planetary gear set 220 includes a sun gear member 222, a ring gear member 224, and a planet carrier assembly member 226. The planet carrier assembly member 226 includes a plurality of pinion gears 227 rotatably mounted on a carrier member 229 and disposed in meshing relationship with both the sun gear member

222 and the ring gear member 224.

[0096] The planetary gear set 230 includes a sun gear member 232, a ring gear member 234, and a planet carrier assembly member 236. The planet carrier assembly member 236 includes a plurality of pinion gears 237 rotatably mounted on a carrier member 239 and disposed in meshing relationship with both the sun gear member 232 and the ring gear member 234.

[0097] The planetary gear set 240 includes a sun gear member 242, a ring gear member 244, and a planet carrier assembly member 246. The planet carrier assembly member 246 includes a plurality of intermeshing pinion gears 247, 248 rotatably mounted on a carrier member 249 and disposed in meshing relationship with the ring gear member 244 and the sun gear member 242, respectively.

[0098] The planetary gear set 250 includes a sun gear member 252, a ring gear member 254, and a planet carrier assembly member 256. The planet carrier assembly member 256 includes a plurality of intermeshing pinion gears 257, 258 rotatably mounted on a carrier member 259 and disposed in meshing relationship with the ring gear member 254 and the sun gear member 252, respectively.

[0099] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 220, 230, 240 and 250 are divided into first and second transmission subsets 260, 261 which are alternatively engaged to provide odd number and even number speed ranges, respectively. Transmission subset 260 includes planetary gear sets 220 and 230, and transmission subset 261 includes planetary gear sets 240 and 250. The output shaft 19 is continuously connected with members of both subsets 260 and 261.

[0100] [00100] As mentioned above, the first and second input clutches 262, 263 are alternatively engaged for transmitting power from the input shaft 17 to transmission subset 260 or transmission subset 261. The first and second input clutches 262, 263 are controlled electronically, and the disengaged input clutch is gradually engaged while the engaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speeds are preselected within the transmission subsets 260, 261 prior to engaging the respective input clutches 262, 263. The preselection is achieved by means of electronically controlled synchronizers. As shown, the planetary gear arrangement includes eight torque transmitting mechanisms 264, 265, 266, 267, 268, 269, 270 and 271. The torque transmitting mechanisms 268 and 269 comprise braking synchronizers, and the torque transmitting mechanisms 264, 265, 266, 267, 270 and 271 comprise rotating synchronizers.

[0101] [00101] Accordingly, the input shaft 17 is alter-

nately connected with the first and second transmission subsets 260, 261 (i.e. through the clutch 262 to the sun gear member 222 and through the clutch 263 to the ring gear member 224). The ring gear member 224 is continuously connected with the transmission housing 280. The planet carrier assembly member 246 is continuously connected with the sun gear member 232 and the output shaft 19 through the interconnecting member 272. The sun gear member 242 is continuously connected with the planet carrier assembly member 256 through the interconnecting member 274.

[0102] [00102] The sun gear member 222 is selectively connectable with the ring gear member 234 through the synchronizer 264. The sun gear member 222 is selectively connectable with the planet carrier assembly member 236 through the synchronizer 265. The planet carrier assembly member 226 is selectively connectable with the ring gear member 234 through the synchronizer 266. The planet carrier assembly member 226 is selectively connectable with the planet carrier assembly member 236 through the synchronizer 267. The ring gear member 254 is selectively connectable with the transmission housing 280 through the braking synchronizer 268. The sun gear member 252 is selectively connectable with the transmission housing 280 through the braking synchronizer 269. The planet carrier assembly member 246 is selectively connectable with the ring gear member 254 through the synchronizer 270. The planet carrier assembly member 246 is selectively connectable with the sun gear member 252 through the synchronizer 271.

[0103] [00103] As shown in Figure 3b, and in particular the truth table disclosed therein, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of three to provide six forward speed ratio and a reverse speed ratio.

[0104] [00104] The reverse speed ratio is established with the engagement of the input clutch 262 and the synchronizers 264, 267. The input clutch 262 connects the sun gear member 222 to the input shaft 17. The synchronizer 264 connects the sun gear member 222 to the ring gear member 234. The synchronizer 267 connects the planet carrier assembly member 226 to the planet carrier assembly member 236. The sun gear member 222 and the ring gear member 234 rotate at the same speed as the input shaft 17. The planet carrier assembly member 226 rotates at the same speed as the planet carrier assembly member 236. The ring gear member 224 does not rotate. The planet carrier assembly member 226 rotates at a speed determined from the speed of the sun gear member 222 and the ring gear/sun gear tooth ratio of the planetary gear set 220. The sun gear member 232 and the planet carrier assembly member 246 rotate at the same speed as the output shaft 19. The sun gear member 232, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 234, the speed of the planet carrier assembly member 236 and the ring gear/sun

gear tooth ratio of the planetary gear set 230. The numerical value of the reverse speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 220, 230.

[0105] [00105] The first forward speed ratio is established with the engagement of the input clutch 262 and the synchronizers 266, 267. The input clutch 262 connects the sun gear member 222 to the input shaft 17. The synchronizer 266 connects the planet carrier assembly member 226 to the ring gear member 234. The synchronizer 267 connects the planet carrier assembly member 226 to the planet carrier assembly member 236. The sun gear member 222 rotates at the same speed as the input shaft 17. The planet carrier assembly members 226, 246 and the planetary gear set 230 rotate at the same speed as the output shaft 19. The ring gear member 224 does not rotate. The planet carrier assembly member 226, and therefore the output shaft 19, rotates at a speed determined from the speed of the sun gear member 222 and the ring gear/sun gear tooth ratio of the planetary gear set 220. The numerical value of the first forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 220.

[0106] [00106] The second forward speed ratio is established with the engagement of the input clutch 263, the braking synchronizer 269 and the synchronizer 270. The input clutch 263 connects the ring gear member 244 to the input shaft 17. The braking synchronizer 269 connects the sun gear member 252 to the transmission housing 280. The synchronizer 270 connects the planet carrier assembly member 246 to the ring gear member 254. The sun gear member 242 rotates at the same speed as the planet carrier assembly member 256. The planet carrier assembly member 246 and the ring gear member 254 rotate at the same speed as the output shaft 19. The ring gear member 244 rotates at the same speed as the input shaft 17. The planet carrier assembly member 246, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 244, the speed of the sun gear member 242 and the ring gear/sun gear tooth ratio of the planetary gear set 240. The sun gear member 252 does not rotate. The planet carrier assembly member 256 rotates at a speed determined from the speed of the ring gear member 254 and the ring gear/sun gear tooth ratio of the planetary gear set 250. The numerical value of second forward speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 240, 250.

[0107] The third forward speed ratio is established with the engagement of the input clutch 262 and the synchronizers 264, 265. In this configuration, the input shaft 17 is directly connected to the output shaft 19. The numerical value of the third forward speed ratio is 1.

[0108] The fourth forward speed ratio is established with the engagement of the input clutch 263 and the braking synchronizers 268, 269. The input clutch 263 connects the ring gear member 244 to the input shaft

17. The braking synchronizer 268 connects the ring gear member 254 to the transmission housing 280. The braking synchronizer 269 connects the sun gear member 252 to the transmission housing 280. The sun gear member 242 and the planetary gear set 250 do not rotate. The planet carrier assembly member 246 rotates at the same speed as the output shaft 19. The ring gear member 244 rotates at the same speed as the input shaft 17. The planet carrier assembly member 246, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 244 and the ring gear/sun gear tooth ratio of the planetary gear set 240. The numerical value of the fourth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 240.

[0109] The fifth forward speed ratio is established with the engagement of the input clutch 262 and the synchronizers 265, 266. The input clutch 262 connects the sun gear member 222 to the input shaft 17. The synchronizer 265 connects the sun gear member 222 to the planet carrier assembly member 236. The synchronizer 266 connects the planet carrier assembly member 226 to the ring gear member 234. The sun gear member 222 and the planet carrier assembly member 236 rotate at the same speed as the input shaft 17. The planet carrier assembly member 226 rotates at the same speed as the ring gear member 234. The ring gear member 224 does not rotate. The planet carrier assembly member 226 rotates at a speed determined from the speed of the sun gear member 222 and the ring gear/sun gear tooth ratio of the planetary gear set 220. The sun gear member 232 and the planet carrier assembly member 246 rotate at the same speed as the output shaft 19. The sun gear member 232, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 234, the speed of the planet carrier assembly member 236 and the ring gear/sun gear tooth ratio of the planetary gear set 230. The numerical value of the fifth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 220, 230.

[0110] The sixth forward speed ratio is established with the engagement of the input clutch 263, the braking synchronizer 268 and the synchronizer 271. The input clutch 263 connects the ring gear member 244 to the input shaft 17. The braking synchronizer 268 connects the ring gear member 254 to the transmission housing 280. The synchronizer 271 connects the planet carrier assembly member 246 to the sun gear member 252. The sun gear member 242 rotates at the same speed as the planet carrier assembly member 256. The planet carrier assembly member 246 and the sun gear member 252 rotate at the same speed as the output shaft 19. The ring gear member 244 rotates at the same speed as the input shaft 17. The planet carrier assembly member 246, and therefore the output shaft 19, rotates at a speed determined from the speed of the ring gear member 244, the speed of the sun gear member 242 and the

ring gear/sun gear tooth ratio of the planetary gear set 240. The ring gear member 254 does not rotate. The planet carrier assembly member 256 rotates at a speed determined from the speed of the sun gear member 252 and the ring gear/sun gear tooth ratio of the planetary gear set 250. The numerical value of the sixth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear set 240, 250.

[0111] As previously set forth, the truth table of Figure 3b describes the combinations of engagements utilized for six forward speed ratios and one reverse speed ratio. The truth table also provides an example of speed ratios that are available with the family member described above. These examples of speed ratios are determined the tooth ratios given in Figure 3b. The R1/S1 value is the tooth ratio of the planetary gear set 220; the R2/S2 value is the tooth ratio of the planetary gear set 230; the R3/S3 value is the tooth ratio of the planetary gear set 240; and the R4/S4 value is the tooth ratio of the planetary gear set 250. Also depicted in Figure 3b is a chart representing the ratio steps between adjacent forward speed ratios and the reverse speed ratio. For example, the first to second ratio interchange has a step of 1.93.

[0112] A powertrain 310, shown in Figure 4a, includes the engine 12, a planetary transmission 314, and the final drive mechanism 16. The planetary transmission 314 includes an input shaft 17 continuously connected with the engine 12, a planetary gear arrangement 318, and an output shaft 19 continuously connected with the final drive mechanism 16. The planetary gear arrangement 318 includes four planetary gear sets 320, 330, 340 and 350.

[0113] The planetary gear set 320 includes a sun gear member 322, a ring gear member 324, and a planet carrier assembly member 326. The planet carrier assembly member 326 includes a plurality of pinion gears 327 rotatably mounted on a carrier member 329 and disposed in meshing relationship with both the sun gear member 322 and the ring gear member 324.

[0114] The planetary gear set 330 includes a sun gear member 332, a ring gear member 334, and a planet carrier assembly member 336. The planet carrier assembly member 336 includes a plurality of pinion gears 337 rotatably mounted on a carrier member 339 and disposed in meshing relationship with both the sun gear member 332 and the ring gear member 334.

[0115] The planetary gear set 340 includes a sun gear member 342, a ring gear member 344, and a planet carrier assembly member 346. The planet carrier assembly member 346 includes a plurality of intermeshing pinion gears 347, 348 rotatably mounted on a carrier member 349 and disposed in meshing relationship with the ring gear member 344 and the sun gear member 342, respectively.

[0116] The planetary gear set 350 includes a sun gear member 352, a ring gear member 354, and a planet carrier assembly member 356. The planet carrier assembly member 356 includes a plurality of intermeshing pinion

gears 357, 358 rotatably mounted on a carrier member 359 and disposed in meshing relationship with the ring gear member 354 and the sun gear member 352, respectively.

[0117] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 320, 330, 340 and 350 are divided into first and second transmission subsets 360, 361 which are alternatively engaged to provide odd number and even number speed ranges, respectively. Transmission subset 360 includes planetary gear sets 320 and 330, and transmission subset 361 includes planetary gear sets 340 and 350. The output shaft 19 is continuously connected with members of both subsets 360 and 361.

[0118] As mentioned above, the first and second input clutches 362, 363 are alternatively engaged for transmitting power from the input shaft 17 to transmission subset 360 or transmission subset 361. The first and second input clutches 362, 363 are controlled electronically, and the disengaged input clutch is gradually disengaged while the engaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speeds are preselected within the transmission subsets 360, 361 prior to engaging the respective input clutches 362, 363. The preselection is achieved by means of electronically controlled synchronizers. As shown, the planetary gear arrangement includes eight torque transmitting mechanisms 364, 365, 366, 367, 368, 369, 370 and 371. The torque transmitting mechanisms 368 and 369 comprise braking synchronizers, and the torque transmitting mechanisms 364, 365, 366, 367, 370 and 371 comprise rotating synchronizers.

[0119] Accordingly, the input shaft 17 is alternately connected with the first and second transmission subsets 360, 361 (i.e. through the clutch 362 to the sun gear member 332 and through the clutch 363 to the ring gear member 344). The sun gear member 322 is continuously connected with the transmission housing 380. The ring gear member 324 is continuously connected with the planet carrier assembly member 336 through the interconnecting member 372. The planet carrier assembly member 346 is continuously connected with the ring gear member 334 and the output shaft 19 through the interconnecting member 374. The sun gear member 342 is continuously connected with the planet carrier assembly member 356 through the interconnecting member 376.

[0120] The planet carrier assembly member 336 is selectively connectable with the sun gear member 322 through the synchronizer 364. The planet carrier assembly member 326 is selectively connectable with the ring gear member 334 through the synchronizer 365. The planet carrier assembly member 326 is selectively con-

nectable with the sun gear member 332 through the synchronizer 366. The ring gear member 324 is selectively connectable with the planet carrier assembly member 326 through the synchronizer 367. The ring gear member 354 is selectively connectable with the transmission housing 380 through the braking synchronizer 368. The sun gear member 352 is selectively connectable with the transmission housing 380 through the braking synchronizer 369. The planet carrier assembly member 346 is selectively connectable with ring gear member 354 through the synchronizer 370. The planet carrier assembly member 346 is selectively connectable with the sun gear member 352 through the synchronizer 371.

[0121] The truth tables given in Figures 4b, 5b, 6b, 7b, 8b, 9b, 10b, 11b, 12b and 13b show the engagement sequences for the torque transmitting mechanisms to provide at least five forward speed ratios and one reverse speed ratio. As shown and described above for the configurations in Figures 1a, 2a and 3a, those skilled in the art will understand from the respective truth tables how the speed ratios are established through the planetary gear sets identified in the written description.

[0122] The truth table shown in Figure 4b describes the engagement combination and engagement sequence necessary to provide the reverse drive ratio and six forward speed ratios. A sample of the numerical values for the ratios is also provided in the truth table of Figure 4b. These values are determined utilizing the ring gear/sun gear tooth ratios also given in Figure 4b. The R1/S1 value is the tooth ratio for the planetary gear set 320; the R2/S2 value is the tooth ratio for the planetary gear set 330; the R3/S3 value is the tooth ratio for the planetary gear set 340; and the R4/S4 value is the tooth ratio for the planetary gear set 350. Also given in Figure 4b is a chart describing the step ratios between the adjacent forward speed ratios and the reverse to first forward speed ratio. For example, the first to second forward speed ratio step is 2.05.

[0123] Those skilled in the art will recognize that the numerical value of the reverse speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 330. The numerical values of the first and fifth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 320, 330. The numerical values of the second and sixth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 340, 350. The numerical value of the third forward speed ratio is 1. The numerical value of the fourth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 340.

[0124] A powertrain 410 shown in Figure 5a includes a conventional engine 12, a planetary transmission 414, and a conventional final drive mechanism 16. The planetary transmission 414 includes an input shaft 17 connected with the engine 12, a planetary gear arrangement 418, and an output shaft 19 continuously connected with the final drive mechanism 16. The planetary gear

arrangement 418 includes four planetary gear sets 420, 430, 440 and 450.

[0125] The planetary gear set 420 includes a sun gear member 422, a ring gear member 424, and a planet carrier assembly member 426. The planet carrier assembly member 426 includes a plurality of pinion gears 427 rotatably mounted on a carrier member 429 and disposed in meshing relationship with both the sun gear member 422 and the ring gear member 424.

[0126] The planetary gear set 430 includes a sun gear member 432, a ring gear member 434, and a planet carrier assembly member 436. The planet carrier assembly member 436 includes a plurality of pinion gears 437 rotatably mounted on a carrier member 439 and disposed in meshing relationship with both the sun gear member 432 and the ring gear member 434.

[0127] The planetary gear set 440 includes a sun gear member 442, a ring gear member 444, and a planet carrier assembly member 446. The planet carrier assembly member 446 includes a plurality of intermeshing pinion gears 447, 448 rotatably mounted on a carrier member 449 and disposed in meshing relationship with the ring gear member 444 and the sun gear member 442, respectively.

[0128] The planetary gear set 450 includes a sun gear member 452, a ring gear member 454, and a planet carrier assembly member 456. The planet carrier assembly member 456 includes a plurality of intermeshing pinion gears 457, 458 rotatably mounted on a carrier member 459 and disposed in meshing relationship with the ring gear member 454 and the sun gear member 452, respectively.

[0129] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 420, 430, 440 and 450 are divided into first and second transmission subsets 460, 461 which are alternatively engaged to provide odd number and even number speed ranges, respectively. Transmission subset 460 includes planetary gear sets 420 and 430, and transmission subset 461 includes planetary gear sets 440 and 450. The output shaft 19 is continuously connected with members of both subsets 460 and 461.

[0130] As mentioned above, the first and second input clutches 462, 463 are alternatively engaged for transmitting power from the input shaft 17 to transmission subset 460 or transmission subset 461. The first and second input clutches 462, 463 are controlled electronically, and the disengaged input clutch is gradually engaged while the engaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speeds are preselected within the transmission subsets 460, 461 prior to engaging the respective input clutches 462, 463. The preselection is achieved by means of electronically con-

trolled synchronizers. As shown, the planetary gear arrangement includes eight torque transmitting mechanisms 464, 465, 466, 467, 468, 469, 470 and 471. The torque transmitting mechanisms 468 and 469 comprise braking synchronizers, and the torque transmitting mechanisms 464, 465, 466, 467, 470 and 471 comprise rotating synchronizers.

[0131] Accordingly, the input shaft 17 is alternately connected with the first and second transmission subsets 460, 461 (i.e. through the clutch 462 to the sun gear member 432 and through the clutch 463 to the ring gear member 444). The sun gear member 422 is continuously connected with the transmission housing 480. The ring gear member 424 is continuously connected with the planet carrier assembly member 436 through the interconnecting member 472. The planet carrier assembly member 446 is continuously connected with the ring gear member 434 and the output shaft 19 through the interconnecting member 474. The sun gear member 442 is continuously connected with the sun gear member 452 through the interconnecting member 476.

[0132] The planet carrier assembly member 436 is selectively connectable with the sun gear member 432 through the synchronizer 464. The planet carrier assembly member 426 is selectively connectable with the ring gear member 434 through the synchronizer 465. The planet carrier assembly member 426 is selectively connectable with the sun gear member 432 through the synchronizer 466. The ring gear member 424 is selectively connectable with the planet carrier assembly member 426 through the synchronizer 467. The ring gear member 454 is selectively connectable with the transmission housing 480 through the braking synchronizer 468. The planet carrier assembly member 456 is selectively connectable with the transmission housing 480 through the braking synchronizer 469. The planet carrier assembly member 446 is selectively connectable with the ring gear member 454 through the synchronizer 470. The planet carrier assembly member 446 is selectively connectable with the planet carrier assembly member 456 through the synchronizer 471.

[0133] As shown in Figure 5b, and in particular the truth table disclosed therein, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of at least two to provide six forward speed ratios and a reverse speed ratio.

[0134] Figure 5b also provides a chart of the ratio steps between adjacent forward ratios and between the reverse and first ratio. For example, the ratio step between the first and second forward ratios is 2.05. Those skilled in the art will recognize that the numerical value of the reverse speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 430. The numerical values of the first and fifth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 420, 430. The numerical values of the second and sixth forward speed ratios are determined utilizing the ring gear/sun gear

tooth ratios of the planetary gear sets 440, 450. The numerical value of the third forward speed ratio is 1. The numerical value of the fourth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 440.

[0135] A powertrain 510, shown in Figure 6a, includes a conventional engine 12, a powertrain 514, and a conventional final drive mechanism 16. The powertrain 514 includes an input shaft 17 connected with the engine 12, a planetary gear arrangement 518, and an output shaft 19 continuously connected with the final drive mechanism 16. The planetary gear arrangement 518 includes four planetary gear sets 520, 530, 540 and 550.

[0136] The planetary gear set 520 includes a sun gear member 522, a ring gear member 524, and a planet carrier assembly member 526. The planet carrier assembly member 526 includes a plurality of pinion gears 527 rotatably mounted on a carrier member 529 and disposed in meshing relationship with both the sun gear member 522 and the ring gear member 524.

[0137] The planetary gear set 530 includes a sun gear member 532, a ring gear member 534, and a planet carrier assembly member 536. The planet carrier assembly member 536 includes a plurality of pinion gears 537 rotatably mounted on a carrier member 539 and disposed in meshing relationship with both the sun gear member 532 and the ring gear member 534.

[0138] The planetary gear set 540 includes a sun gear member 542, a ring gear member 544, and a planet carrier assembly member 546. The planet carrier assembly member 546 includes a plurality of intermeshing pinion gears 547, 548 rotatably mounted on a carrier member 549 and disposed in meshing relationship with the ring gear member 544 and the sun gear member 542, respectively.

[0139] The planetary gear set 550 includes a sun gear member 552, a ring gear member 554, and a planet carrier assembly member 556. The planet carrier assembly member 556 includes a plurality of intermeshing pinion gears 557, 558 rotatably mounted on a carrier member 559 and disposed in meshing relationship with the ring gear member 554 and the sun gear member 552, respectively.

[0140] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 520, 530, 540 and 550 are divided into first and second transmission subsets 560, 561 which are alternatively engaged to provide odd number and even number speed ranges, respectively. Transmission subset 560 includes planetary gear sets 520 and 530, and transmission subset 561 includes planetary gear sets 540 and 550. The output shaft 19 is continuously connected with members of both subsets 560 and 561.

[0141] As mentioned above, the first and second input clutches 562, 563 are alternatively engaged for transmitting power from the input shaft 17 to transmission subset 560 or transmission subset 561. The first and second input clutches 562, 563 are controlled electron-

ically, and the disengaged input clutch is gradually engaged while the engaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speeds are preselected within the transmission subsets 560, 561 prior to engaging the respective input clutches 562, 563. The preselection is achieved by means of electronically controlled synchronizers. As shown, the planetary gear arrangement includes eight torque transmitting mechanisms 564, 565, 566, 567, 568, 569, 570 and 571. The torque transmitting mechanisms 568 and 569 comprise braking synchronizers, and the torque transmitting mechanisms 564, 565, 566, 567, 570 and 571 comprise rotating synchronizers.

[0142] Accordingly, the input shaft 17 is alternately connected with the first and second transmission subsets 560, 561 (i.e. through the clutch 562 to the sun gear member 522 and through the clutch 563 to the ring gear member 544). The ring gear member 524 is continuously connected with the transmission housing 580. The planet carrier assembly member 546 is continuously connected with the sun gear member 532 and the output shaft 19 through the interconnecting member 572. The sun gear member 542 is continuously connected with the sun gear member 552 through the interconnecting member 574.

[0143] The sun gear member 522 is selectively connectable with the ring gear member 534 through the synchronizer 564. The sun gear member 522 is selectively connectable with the planet carrier assembly member 536 through the synchronizer 565. The planet carrier assembly member 526 is selectively connectable with the ring gear member 534 through the synchronizer 566. The planet carrier assembly member 526 is selectively connectable with the planet carrier assembly member 536 through the synchronizer 567. The ring gear member 554 is selectively connectable with the transmission housing 580 through the braking synchronizer 568. The planet carrier assembly member 556 is selectively connectable with the transmission housing 580 through the braking synchronizer 569. The planet carrier assembly member 546 is selectively connectable with the ring gear member 554 through the synchronizer 570. The planet carrier assembly member 546 is selectively connectable with the planet carrier assembly member 556 through the synchronizer 571.

[0144] As shown in Figure 6b, and in particular the truth table disclosed therein, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of three to provide six forward speed ratios and a reverse speed ratio. The chart of Figure 6b describes the ratio steps between adjacent forward speed ratios and the ratio step between the reverse and first forward speed ratio.

[0145] Those skilled in the art, upon reviewing the truth table and the schematic representation of Figure 6a can determine that the numerical values of the reverse and fifth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 520, 530. The numerical value of the first forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 520. The numerical values of the second and sixth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 540, 550. The numerical value of the third forward speed ratio is 1. The numerical value of the fourth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 540.

[0146] The sample speed ratios given in the truth table are determined utilizing the tooth ratio values also given in Figure 6b. R1/S1 value is the tooth ratio of the planetary gear set 520; the R2/S2 value is the tooth ratio of the planetary gear set 530; the R3/S3 value is the tooth ratio of the planetary gear set 540; and the R4/S4 value is the tooth ratio of the planetary gear set 550.

[0147] A powertrain 610, shown in Figure 7a, has the engine and torque converter 12, a planetary transmission 614, and the final drive mechanism 16. The planetary transmission 614 includes the input shaft 17, a planetary gear arrangement 618, and the output shaft 19. The planetary gear arrangement 618 includes four planetary gear sets 620, 630, 640 and 650.

[0148] The planetary gear set 620 includes a sun gear member 622, a ring gear member 624, and a planet carrier assembly member 626. The planet carrier assembly member 626 includes a plurality of pinion gears 627 rotatably mounted on a carrier member 629 and disposed in meshing relationship with both the sun gear member 622 and the ring gear member 624.

[0149] The planetary gear set 630 includes a sun gear member 632, a ring gear member 634, and a planet carrier assembly member 636. The planet carrier assembly member 636 includes a plurality of intermeshing pinion gears 637, 638 rotatably mounted on a carrier member 639 and disposed in meshing relationship with the ring gear member 634 and the sun gear member 632, respectively.

[0150] The planetary gear set 640 includes a sun gear member 642, a ring gear member 644, and a planet carrier assembly member 646. The planet carrier assembly member 646 includes a plurality of pinion gears 647 rotatably mounted on a carrier member 649 and disposed in meshing relationship with both the sun gear member 642 and the ring gear member 644.

[0151] The planetary gear set 650 includes a sun gear member 652, a ring gear member 654, and a planet carrier assembly member 656. The planet carrier assembly member 656 includes a plurality of intermeshing pinion gears 657, 658 rotatably mounted on a carrier member 659 and disposed in meshing relationship with the ring gear member 654 and the sun gear member 652, re-

spectively.

[0152] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 620, 630, 640 and 650 are divided into first and second transmission subsets 660, 661 which are alternatively engaged to provide odd number and even number speed ranges, respectively. Transmission subset 660 includes planetary gear sets 620 and 630, and transmission subset 661 includes planetary gear sets 640 and 650. The output shaft 19 is continuously connected with members of both subsets 660 and 661.

[0153] As mentioned above, the first and second input clutches 662, 663 are alternatively engaged for transmitting power from the input shaft 17 to transmission subset 660 or transmission subset 661. The first and second input clutches 662, 663 are controlled electronically, and the disengaged input clutch is gradually engaged while the engaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speeds are preselected within the transmission subsets 660, 661 prior to engaging the respective input clutches 662, 663. The preselection is achieved by means of electronically controlled synchronizers. As shown, the planetary gear arrangement includes eight torque transmitting mechanisms 664, 665, 666, 667, 668, 669, 670 and 671. The torque transmitting mechanisms 668 and 669 comprise braking synchronizers, and the torque transmitting mechanisms 664, 665, 666, 667, 670 and 671 comprise rotating synchronizers.

[0154] Accordingly, the input shaft 17 is alternately connected with the first and second transmission subsets 660, 661 (i.e. through the clutch 662 to the sun gear member 622 and through the clutch 663 to the ring gear member 644). The ring gear member 624 is continuously connected with the transmission housing 680. The planet carrier assembly member 646 is continuously connected with the sun gear member 632, the output shaft 19 and the ring gear member 654 through the interconnecting member 672.

[0155] The sun gear member 622 is selectively connectable with the ring gear member 634 through the synchronizer 664. The sun gear member 622 is selectively connectable with the planet carrier assembly member 636 through the synchronizer 665. The ring gear member 624 is selectively connectable with the planet carrier assembly member 636 through the synchronizer 666. The planet carrier assembly member 626 is selectively connectable with the ring gear member 634 through the synchronizer 667. The planet carrier assembly member 656 is selectively connectable with the transmission housing 680 through the braking synchronizer 668. The sun gear member 652 is selectively connectable with the transmission housing 680 through the braking syn-

chronizer 669. The sun gear member 642 is selectively connectable with the planet carrier assembly member 656 through the synchronizer 670. The sun gear member 642 is selectively connectable with the sun gear member 652 through the synchronizer 671.

[0156] As shown in Figure 7b, and in particular the truth table disclosed therein, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of three to provide six forward speed ratios and a reverse speed ratio. The ratio values given are by way example and are established utilizing the ring gear/sun gear tooth ratios given in Figure 7b. For example, the R1/S2 value is the tooth ratio of the planetary gear set 620; the R2/S2 value is the tooth ratio of the planetary gear set 630; the R3/S3 value is the tooth ratio of the planetary gear set 640; and the R4/S4 value is the tooth ratio of the planetary gear set 650. The ratio steps between adjacent forward ratios and the reverse to first ratio are also given in Figure 7b.

[0157] Those skilled in the art will, upon reviewing the truth table of Figure 7b, recognize that the numerical values of the reverse and first forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 620, 630. The numerical value of the second forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 640. The numerical value of the third forward speed ratio is 1. The numerical values of the fourth and sixth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 640, 650. The numerical value of the fifth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 630.

[0158] A powertrain 710, shown in Figure 8a, has the conventional engine 12, a planetary transmission 714, and the conventional final drive mechanism 16. The engine 12 is continuously connected with the input shaft 17. The planetary transmission 714 is drivingly connected with the final drive mechanism 16 through the output shaft 19. The planetary transmission 714 includes a planetary gear arrangement 718 that has a first planetary gear set 720, a second planetary gear set 730, a third planetary gear set 740, and a fourth planetary gear set 750.

[0159] The planetary gear set 720 includes a sun gear member 722, a ring gear member 724, and a planet carrier assembly member 726. The planet carrier assembly member 726 includes a plurality of pinion gears 727 rotatably mounted on a carrier member 729 and disposed in meshing relationship with both the sun gear member 722 and the ring gear member 724.

[0160] The planetary gear set 730 includes a sun gear member 732, a ring gear member 734, and a planet carrier assembly member 736. The planet carrier assembly member 736 includes a plurality of intermeshing pinion gears 737, 738 rotatably mounted on a carrier member 739 and disposed in meshing relationship with the ring gear member 734 and the sun gear member 732, re-

spectively.

[0161] The planetary gear set 740 includes a sun gear member 742, a ring gear member 744, and a planet carrier assembly member 746. The planet carrier assembly member 746 includes a plurality of pinion gears 747 rotatably mounted on a carrier member 749 and disposed in meshing relationship with both the sun gear member 742 and the ring gear member 744.

[0162] The planetary gear set 750 includes a sun gear member 752, a ring gear member 754, and a planet carrier assembly member 756. The planet carrier assembly member 756 includes a plurality of intermeshing pinion gears 757, 758 rotatably mounted on a carrier member 759 and disposed in meshing relationship with the ring gear member 754 and the sun gear member 752, respectively.

[0163] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 720, 730, 740 and 750 are divided into first and second transmission subsets 760, 761 which are alternatively engaged to provide odd number and even number speed ranges, respectively. Transmission subset 760 includes planetary gear sets 720 and 730, and transmission subset 761 includes planetary gear sets 740 and 750. The output shaft 19 is continuously connected with members of both subsets 760 and 761.

[0164] As mentioned above, the first and second input clutches 762, 763 are alternatively engaged for transmitting power from the input shaft 17 to transmission subset 760 or transmission subset 761. The first and second input clutches 762, 763 are controlled electronically, and the disengaged input clutch is gradually engaged while the engaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speeds are preselected within the transmission subsets 760, 761 prior to engaging the respective input clutches 762, 763. The preselection is achieved by means of electronically controlled synchronizers. As shown, the planetary gear arrangement includes eight torque transmitting mechanisms 764, 765, 766, 767, 768, 769, 770 and 771. The torque transmitting mechanisms 768 and 769 comprise braking synchronizers, and the torque transmitting mechanisms 764, 765, 766, 767, 770 and 771 comprise rotating synchronizers.

[0165] Accordingly, the input shaft 17 is alternately connected with the first and second transmission subsets 760, 761 (i.e. through the clutch 762 to the sun gear member 722 and through the clutch 763 to the ring gear member 744). The ring gear member 724 is continuously connected with the transmission housing 780. The planet carrier assembly member 746 is continuously connected with the sun gear member 732, the output shaft 19 and the ring gear member 754 through the in-

terconnecting member 772.

[0166] The sun gear member 722 is selectively connectable with the ring gear member 734 through the synchronizer 764. The sun gear member 722 is selectively connectable with the planet carrier assembly member 736 through the synchronizer 765. The planet carrier assembly member 726 is selectively connectable with the ring gear member 734 through the synchronizer 766. The planet carrier assembly member 726 is selectively connectable with the planet carrier assembly member 736 through the synchronizer 767. The planet carrier assembly member 756 is selectively connectable with the transmission housing 780 through the braking synchronizer 768. The sun gear member 752 is selectively connectable with the transmission housing 780 through the braking synchronizer 769. The sun gear member 742 is selectively connectable with the planet carrier assembly member 756 through the synchronizer 770. The sun gear member 742 is selectively connectable with the sun gear member 752 through the synchronizer 771.

[0167] As shown in Figure 8b, and in particular the truth table disclosed therein, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of three to provide six forward speed ratios and a reverse speed ratio. Also given in the truth table is a set of numerical values that are attainable with the present invention utilizing the ring gear/sun gear tooth ratios given in Figure 8b. The R1/S1 value is the tooth ratio of the planetary gear set 720; the R2/S2 value is the tooth ratio of the planetary gear set 730; the R3/S3 value is the tooth ratio of the planetary gear set 740; and the R4/S4 value is the tooth ratio of the planetary gear set 750.

[0168] Figure 8b also provides a chart of the ratio steps between adjacent forward ratios and between the reverse and first forward ratio. For example, the ratio step between the first and second forward ratios is 1.98.

[0169] Those skilled in the art will recognize that the numerical values of the reverse and fifth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 720, 730. The numerical value of the first forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 720. The numerical value of the second forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 740. The numerical value of the third forward speed ratio is 1. The numerical values of the fourth and sixth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 740, 750.

[0170] A powertrain 810, shown in Figure 9a, has the conventional engine 12, a planetary transmission 814, and the final drive mechanism 16. The engine 12 is continuously connected with the input shaft 17. The planetary transmission 814 is drivingly connected with final drive mechanism 16 through output shaft 19. The planetary transmission 814 includes a planetary gear arrangement 818 that has a first planetary gear set 820,

a second planetary gear set 830, a third planetary gear set 840, and fourth planetary gear set 850.

[0171] The planetary gear set 820 includes a sun gear member 822, a ring gear member 824, and a planet carrier assembly member 826. The planet carrier assembly member 826 includes a plurality of intermeshing pinion gears 827, 828 rotatably mounted on a carrier member 829 and disposed in meshing relationship with the ring gear member 824 and the sun gear member 822, respectively.

[0172] The planetary gear set 830 includes a sun gear member 832, a ring gear member 834, and a planet carrier assembly member 836. The planet carrier assembly member 836 includes a plurality of pinion gears 837 rotatably mounted on a carrier member 839 and disposed in meshing relationship with both the sun gear member 832 and the ring gear member 834.

[0173] The planetary gear set 840 includes a sun gear member 842, a ring gear member 844, and a planet carrier assembly member 846. The planet carrier assembly member 846 includes a plurality of intermeshing pinion gears 847, 848 rotatably mounted on a carrier member 849 and disposed in meshing relationship with the ring gear member 844 and the sun gear member 842, respectively.

[0174] The planetary gear set 850 includes a sun gear member 852, a ring gear member 854, and a planet carrier assembly member 856. The planet carrier assembly member 856 includes a plurality of pinion gears 857 rotatably mounted on a carrier member 859 and disposed in meshing relationship with both the sun gear member 852 and the ring gear member 854.

[0175] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 820, 830, 840 and 850 are divided into first and second transmission subsets 860, 861 which are alternatively engaged to provide odd number and even number speed ranges, respectively. Transmission subset 860 includes planetary gear sets 820 and 830, and transmission subset 861 includes planetary gear sets 840 and 850. The output shaft 19 is continuously connected with members of both subsets 860 and 861.

[0176] As mentioned above, the first and second input clutches 862, 863 are alternatively engaged for transmitting power from the input shaft 17 to transmission subset 860 or transmission subset 861. The first and second input clutches 862, 863 are controlled electronically, and the disengaged input clutch is gradually engaged while the engaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speed selection is preselected within the transmission subsets 860, 861 prior to engaging the respective input clutches 862, 863. The preselection is achieved by means of electronically

controlled synchronizers. As shown, the planetary gear arrangement includes eight torque transmitting mechanisms 864, 865, 866, 867, 868, 869, 870 and 871. The torque transmitting mechanisms 868 and 869 comprise braking synchronizers, and the torque transmitting mechanisms 864, 865, 866, 867, 870 and 871 comprise rotating synchronizers.

[0177] Accordingly, the input shaft 17 is alternately connected with the first and second transmission subsets 860, 861 (i.e. through the clutch 862 to the synchronizers 864 and 865, and through the clutch 863 to the ring gear member 844). The sun gear member 822 is continuously connected with the transmission housing 880. The ring gear member 824 is continuously connected with the planet carrier assembly member 836 through the interconnecting member 872. The planet carrier assembly member 846 is continuously connected with the ring gear member 834 and the output shaft 19 through the interconnecting member 874. The sun gear member 842 is continuously connected with the sun gear member 852 through the interconnecting member 876.

[0178] The sun gear member 832 is selectively connectable with the input shaft 17 through the synchronizer 864 and the input clutch 862. The planet carrier assembly member 836 is selectively connectable with the input shaft 17 through the synchronizer 865 and the input clutch 862. The planet carrier assembly member 826 is selectively connectable with the ring gear member 834 through the synchronizer 866. The planet carrier assembly member 826 is selectively connectable with the sun gear member 832 through the synchronizer 867. The ring gear member 854 is selectively connectable with the transmission housing 880 through the braking synchronizer 868. The planet carrier assembly member 856 is selectively connectable with the transmission housing 880 through the braking synchronizer 869. The planet carrier assembly member 846 is selectively connectable with the ring gear member 854 through the synchronizer 870. The planet carrier assembly member 846 is selectively connectable with the planet carrier assembly member 856 through the synchronizer 871.

[0179] As shown in Figure 9b, and in particular the truth table disclosed therein, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of three to provide six forward speed ratios and a reverse speed ratio. A sample of numerical values for the individual ratios is also given in the truth table of Figure 9b. These numerical values have been calculated using the ring gear/sun gear tooth ratios also given by way of example in Figure 9b. The R1/S1 value is the tooth ratio of the planetary gear set 820; the R2/S2 value is the tooth ratio of planetary gear set 830; the R3/S3 value is the tooth ratio of the planetary gear set 840; and the R4/S4 value is the tooth ratio of the planetary gear set 850. Figure 9b also describes the ratio steps between adjacent forward ratios and between the reverse and first forward ratio. For example, the ratio step between the first and second forward ra-

tios is 1.56.

[0180] Those skilled in the art will recognize that the numerical values of the reverse and first forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 840, 850. The numerical value of the second forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 820. The numerical value of the third forward speed ratio is 1. The numerical values of the fourth and sixth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 820, 830. The numerical value of the fifth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 840.

[0181] Referring to Figure 10a, a powertrain 910 is shown having a conventional engine 12, a planetary transmission 914, and a conventional final drive mechanism 16. The planetary transmission 914 includes an input shaft 17 connected with the engine 12, a planetary gear arrangement 918, and an output shaft 19 continuously connected with the final drive mechanism 16. The planetary gear arrangement 918 includes four planetary gear sets 920, 930, 940 and 950.

[0182] The planetary gear set 920 includes a sun gear member 922, a ring gear member 924, and a planet carrier assembly member 926. The planet carrier assembly member 926 includes a plurality of intermeshing pinion gears 927, 928 rotatably mounted on a carrier member 929 and disposed in meshing relationship with the ring gear member 924 and the sun gear member 922, respectively.

[0183] The planetary gear set 930 includes a sun gear member 932, a ring gear member 934, and a planet carrier assembly member 936. The planet carrier assembly member 936 includes a plurality of intermeshing pinion gears 937, 938 rotatably mounted on a carrier member 939 and disposed in meshing relationship with the ring gear member 934 and the sun gear member 932, respectively.

[0184] The planetary gear set 940 includes a sun gear member 942, a ring gear member 944, and a planet carrier assembly member 946. The planet carrier assembly member 946 includes a plurality of intermeshing pinion gears 947, 948 rotatably mounted on a carrier member 949 and disposed in meshing relationship with the ring gear member 944 and the sun gear member 942, respectively.

[0185] The planetary gear set 950 includes a sun gear member 952, a ring gear member 954, and a planet carrier assembly member 956. The planet carrier assembly member 956 includes a plurality of pinion gears 957 rotatably mounted on a carrier member 959 and disposed in meshing relationship with both the sun gear member 952 and the ring gear member 954.

[0186] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 920, 930, 940 and 950 are divided into first and second transmission subsets 960, 961 which are alternatively engaged to

provide odd number and even number speed ranges, respectively. Transmission subset 960 includes planetary gear sets 920 and 930, and transmission subset 961 includes planetary gear sets 940 and 950. The output shaft 19 is continuously connected with members of both subsets 960 and 961.

[0187] In this family member, rather than having two input clutches and eight synchronizers, it has three input clutches 963, 964, 965 and six synchronizers. The input clutches 963, 964, 965 are controlled electronically, and the disengaged input clutch is gradually engaged while the engaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speeds are preselected within the transmission subsets 960, 961 prior to engaging the respective input clutch 963 or synchronizers 964, 965. The preselection is achieved by means of electronically controlled synchronizers. As shown, the planetary gear arrangement includes three input clutches 963, 964, 965 and six torque transmitting mechanisms 966, 967, 968, 969, 970 and 971. The torque transmitting mechanisms 968 and 969 comprise braking synchronizers, and the torque transmitting mechanisms 966, 967, 970 and 971 comprise rotating synchronizers.

[0188] Accordingly, the input shaft 17 is alternately connected with the first and second transmission subsets 960, 961 (i.e. through the clutch 964 to the sun gear member 932, through the clutch 965 to the planet carrier assembly member 936 and through the clutch 963 to the ring gear member 944). The sun gear member 922 is continuously connected with the transmission housing 980. The ring gear member 924 is continuously connected with the planet carrier assembly member 936 through the interconnecting member 972. The planet carrier assembly member 946 is continuously connected with the ring gear member 934 and the output shaft 19 through the interconnecting member 974. The sun gear member 942 is continuously connected with the sun gear member 952 through the interconnecting member 976.

[0189] The sun gear member 932 is selectively connectable with the input shaft 17 through the input clutch 964. The planet carrier assembly member 936 is selectively connectable with the input shaft 17 through the input clutch 965. The planet carrier assembly member 926 is selectively connectable with the ring gear member 934 through the synchronizer 966. The planet carrier assembly member 926 is selectively connectable with the sun gear member 932 through the synchronizer 967. The ring gear member 954 is selectively connectable with the transmission housing 980 through the braking synchronizer 968. The planet carrier assembly member 956 is selectively connectable with the transmission housing 980 through the braking synchronizer 969. The

planet carrier assembly member 946 is selectively connectable with the ring gear member 954 through the synchronizer 970. The planet carrier assembly member 946 is selectively connectable with the planet carrier assembly member 956 through the synchronizer 971.

[0190] As shown in Figure 10b, and in particular the truth table disclosed therein, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of at least two to provide six forward speed ratio and a reverse speed ratio. The truth table also provides a set of examples for the numerical values for each of the reverse and forward speed ratios. These numerical values have been determined utilizing the ring gear/sun gear tooth ratios given in Figure 10b. The R1/S1 value is the tooth ratio of the planetary gear set 920; the R2/S2 value is the tooth ratio of the planetary gear set 930; the R3/S3 value is the tooth ratio of the planetary gear set 940; and the R4/S4 value is the tooth ratio of the planetary gear set 950.

[0191] Those skilled in the art, upon reviewing the engagement combinations, will recognize that the numerical values of the reverse and first forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 940, 950. The numerical values of the second and fourth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 920, 930. The numerical value of the third forward speed ratio is 1. The numerical value of the fifth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 940. The numerical value of the sixth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 920.

[0192] Referring to Figure 11a, a powertrain 1010 is shown having a conventional engine 12, a planetary transmission 1014, and a conventional final drive mechanism 16. The planetary transmission 1014 includes an input shaft 17 connected with the engine 12, a planetary gear arrangement 1018, and an output shaft 19 continuously connected with the final drive mechanism 16. The planetary gear arrangement 1018 includes four planetary gear sets 1020, 1030, 1040 and 1050.

[0193] The planetary gear set 1020 includes a sun gear member 1022, a ring gear member 1024, and a planet carrier assembly member 1026. The planet carrier assembly member 1026 includes a plurality of pinion gears 1027 rotatably mounted on a carrier member 1029 and disposed in meshing relationship with both the sun gear member 1022 and the ring gear member 1024.

[0194] The planetary gear set 1030 includes a sun gear member 1032, a ring gear member 1034, and a planet carrier assembly member 1036. The planet carrier assembly member 1036 includes a plurality of intermeshing pinion gears 1037, 1038 rotatably mounted on a carrier member 1039 and disposed in meshing relationship with the ring gear member 1034 and the sun gear member 1032, respectively.

[0195] The planetary gear set 1040 includes a sun

gear member 1042, a ring gear member 1044, and a planet carrier assembly member 1046. The planet carrier assembly member 1046 includes a plurality of intermeshing pinion gears 1047, 1048 rotatably mounted on a carrier member 1049 and disposed in meshing relationship with the ring gear member 1044 and the sun gear member 1042, respectively.

[0196] The planetary gear set 1050 includes a sun gear member 1052, a ring gear member 1054, and a planet carrier assembly member 1056. The planet carrier assembly member 1056 includes a plurality of intermeshing pinion gears 1057, 1058 rotatably mounted on a carrier member 1059 and disposed in meshing relationship with the ring gear member 1054 and the sun gear member 1052, respectively.

[0197] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 1020, 1030, 1040 and 1050 are divided into first and second transmission subsets 1060, 1061 which are alternatively engaged to provide odd number and even number speed ranges, respectively. Transmission subset 1060 includes planetary gear sets 1020 and 1030, and transmission subset 1061 includes planetary gear sets 1040 and 1050. The output shaft 19 is continuously connected with members of both subsets 1060 and 1061.

[0198] As mentioned above, the first and second input clutches 1062, 1063 are alternatively engaged for transmitting power from the input shaft 17 to transmission subset 1060 or transmission subset 1061. The first and second input clutches 1062, 1063 are controlled electronically, and the disengaged input clutch is gradually engaged while the engaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speeds are preselected within the transmission subsets 1060, 1061 prior to engaging the respective input clutches 1062, 1063. The preselection is achieved by means of electronically controlled synchronizers. As shown, the planetary gear arrangement includes eight torque transmitting mechanisms 1064, 1065, 1066, 1067, 1068, 1069, 1070 and 1071. The torque transmitting mechanisms 1068 and 1069 comprise braking synchronizers, and the torque transmitting mechanisms 1064, 1065, 1066, 1067, 1070 and 1071 comprise rotating synchronizers.

[0199] Accordingly, the input shaft 17 is alternately connected with the first and second transmission subsets 1060, 1061 (i.e. through the clutch 1062 to the sun gear member 1022 and through the clutch 1063 to the ring gear member 1024). The ring gear member 1024 is continuously connected with the transmission housing 1080. The planet carrier assembly member 1046 is continuously connected with the sun gear member 1032 and the output shaft 19 through the interconnecting member 1072. The sun gear member 1042 is continu-

ously connected with the sun gear member 1052 through the interconnecting member 1074.

[0200] The sun gear member 1022 is selectively connectable with the ring gear member 1034 through the synchronizer 1064. The sun gear member 1022 is selectively connectable with the planet carrier assembly member 1036 through the synchronizer 1065. The planet carrier assembly member 1026 is selectively connectable with the ring gear member 1034 through the synchronizer 1066. The planet carrier assembly member 1026 is selectively connectable with the planet carrier assembly member 1036 through the synchronizer 1067. The ring gear member 1054 is selectively connectable with the transmission housing 1080 through the braking synchronizer 1068. The planet carrier assembly member 1056 is selectively connectable with the transmission housing 1080 through the braking synchronizer 1069. The planet carrier assembly member 1046 is selectively connectable with the ring gear member 1054 through the synchronizer 1070. The planet carrier assembly member 1046 is selectively connectable with the planet carrier assembly member 1056 through the synchronizer 1071.

[0201] As shown in Figure 11b, and in particular the truth table disclosed therein, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of three to provide six forward speed ratios and a reverse speed ratio. The truth table also provides a set of examples for the numerical values for each of the reverse and forward speed ratios. These numerical values have been determined utilizing the ring gear/sun gear tooth ratios given in Figure 11b. The R1/S1 value is the tooth ratio of the planetary gear set 1020; the R2/S2 value is the tooth ratio of the planetary gear set 1030; the R3/S3 value is the tooth ratio of the planetary gear set 1040; and the R4/S4 value is the tooth ratio of the planetary gear set 1050.

[0202] Those skilled in the art, upon reviewing the engagement combinations, will recognize that the numerical values of the reverse and fifth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 1020, 1030. The numerical value of the first forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 1020. The numerical values of the second and sixth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 1040, 1050. The numerical value of the third forward speed ratio is 1. The numerical value of the fourth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 1040.

[0203] Referring to Figure 12a, a powertrain 1110 is shown having a conventional engine 12, a planetary transmission 1114, and a conventional final drive mechanism 16. The planetary transmission 1114 includes an input shaft 17 connected with the engine 12, a planetary gear arrangement 1118, and an output shaft 19 continuously connected with the final drive mechanism 16.

The planetary gear arrangement 1118 includes four planetary gear sets 1120, 1130, 1140 and 1150.

[0204] The planetary gear set 1120 includes a sun gear member 1122, a ring gear member 1124, and a planet carrier assembly member 1126. The planet carrier assembly member 1126 includes a plurality of pinion gears 1127 rotatably mounted on a carrier member 1129 and disposed in meshing relationship with both the sun gear member 1122 and the ring gear member 1124.

[0205] The planetary gear set 1130 includes a sun gear member 1132, a ring gear member 1134, and a planet carrier assembly member 1136. The planet carrier assembly member 1136 includes a plurality of intermeshing pinion gears 1137, 1138 rotatably mounted on a carrier member 1139 and disposed in meshing relationship with the ring gear member 1134 and the sun gear member 1132, respectively.

[0206] The planetary gear set 1140 includes a sun gear member 1142, a ring gear member 1144, and a planet carrier assembly member 1146. The planet carrier assembly member 1146 includes a plurality of intermeshing pinion gears 1147, 1148 rotatably mounted on a carrier member 1149 and disposed in meshing relationship with the ring gear member 1144 and the sun gear member 1142, respectively.

[0207] The planetary gear set 1150 includes a sun gear member 1152, a ring gear member 1154, and a planet carrier assembly member 1156. The planet carrier assembly member 1156 includes a plurality of intermeshing pinion gears 1157, 1158 rotatably mounted on a carrier member 1159 and disposed in meshing relationship with the ring gear member 1154 and the sun gear member 1152, respectively.

[0208] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 1120, 1130, 1140 and 1150 are divided into first and second transmission subsets 1160, 1161 which are alternatively engaged to provide odd number and even number speed ranges, respectively. Transmission subset 1160 includes planetary gear sets 1120 and 1130, and transmission subset 1161 includes planetary gear sets 1140 and 1150. The output shaft 19 is continuously connected with members of both subsets 1160 and 1161.

[0209] As mentioned above, the first and second input clutches 1162, 1163 are alternatively engaged for transmitting power from the input shaft 17 to transmission subset 1160 or transmission subset 1061. The first and second input clutches 1162, 1163 are controlled electronically, and the disengaged input clutch is gradually engaged while the engaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speeds are preselected within the transmission subsets 1160, 1161 prior to engaging the respective input clutches 1162, 1163. The

preselection is achieved by means of electronically controlled synchronizers. As shown, the planetary gear arrangement includes eight torque transmitting mechanisms 1164, 1165, 1166, 1167, 1168, 1169, 1170 and 1171. The torque transmitting mechanisms 1168 and 1169 comprise braking synchronizers, and the torque transmitting mechanisms 1164, 1165, 1166, 1167, 1170 and 1171 comprise rotating synchronizers.

[0210] Accordingly, the input shaft 17 is alternately connected with the first and second transmission sub-sets 1160, 1161 (i.e. through the clutch 1162 to the sun gear member 1122 and through the clutch 1163 to the ring gear member 1144). The ring gear member 1124 is continuously connected with the transmission housing 1180. The planet carrier assembly member 1146 is continuously connected with the sun gear member 1132 and the output shaft 19 through the interconnecting member 1172. The sun gear member 1142 is continuously connected with the planet carrier assembly member 1156 through the interconnecting member 1174.

[0211] The sun gear member 1122 is selectively connectable with the ring gear member 1134 through the synchronizer 1164. The sun gear member 1122 is selectively connectable with the planet carrier assembly member 1136 through the synchronizer 1165. The planet carrier assembly member 1126 is selectively connectable with the ring gear member 1134 through the synchronizer 1166. The planet carrier assembly member 1126 is selectively connectable with the planet carrier assembly member 1136 through the synchronizer 1167. The ring gear member 1154 is selectively connectable with the transmission housing 1180 through the braking synchronizer 1168. The sun gear member 1152 is selectively connectable with the transmission housing 1180 through the braking synchronizer 1169. The planet carrier assembly member 1146 is selectively connectable with the ring gear member 1154 through the synchronizer 1170. The planet carrier assembly member 1146 is selectively connectable with the sun gear member 1152 through the synchronizer 1171.

[0212] As shown in Figure 12b, and in particular the truth table disclosed therein, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of three to provide six forward speed ratios and a reverse speed ratio. The truth table also provides a set of examples for the numerical values for each of the reverse and forward speed ratios. These numerical values have been determined utilizing the ring gear/sun gear tooth ratios given in Figure 12b. The R1/S1 value is the tooth ratio of the planetary gear set 1120; the R2/S2 value is the tooth ratio of the planetary gear set 1130; the R3/S3 value is the tooth ratio of the planetary gear set 1140; and the R4/S4 value is the tooth ratio of the planetary gear set 1150.

[0213] Those skilled in the art, upon reviewing the engagement combinations, will recognize that the numerical values of the reverse and fifth forward speed ratios are determined utilizing the ring gear/sun gear tooth ra-

tios of the planetary gear sets 1120, 1130. The numerical value of the first forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 1120. The numerical values of the second and sixth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 1140, 1150. The numerical value of the third forward speed ratio is 1. The numerical value of the fourth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 1140.

[0214] Figures 13a and 13b illustrate a transmission wherein one of the torque transmitting mechanisms from a previously described configuration is eliminated to realize five forward speed ratios and a reverse speed ratio. Specifically, the powertrain 1210, shown in Figure 13a is identical to that shown in Figure 12a, except that the synchronizer 1171 of Figure 12a has been eliminated.

[0215] The powertrain 1210, shown in Figure 13a, includes the conventional engine 12, a planetary transmission 1214, and the conventional final drive mechanism 16. The engine 12 is selectively connectable with the planetary transmission 1214 through the input shaft 17. The planetary transmission is drivingly connected with the final drive mechanism 16 through the input shaft 17. The planetary transmission 1214 includes a planetary gear arrangement 1218 that has a first planetary gear set 1220, a second planetary gear set 1230, a third planetary gear set 1240, and a fourth planetary gear set 1250.

[0216] The planetary gear set 1220 includes a sun gear member 1222, a ring gear member 1224, and a planet carrier assembly member 1226. The planet carrier assembly member 1226 includes a plurality of pinion gears 1227 rotatably mounted on a carrier member 1229 and disposed in meshing relationship with both the sun gear member 1222 and the ring gear member 1224.

[0217] The planetary gear set 1230 includes a sun gear member 1232, a ring gear member 1234, and a planet carrier assembly member 1236. The planet carrier assembly member 1236 includes a plurality of intermeshing pinion gears 1237, 1238 rotatably mounted on a carrier member 1239 and disposed in meshing relationship with the ring gear member 1234 and the sun gear member 1232, respectively.

[0218] The planetary gear set 1240 includes a sun gear member 1042, a ring gear member 1244, and a planet carrier assembly member 1246. The planet carrier assembly member 1246 includes a plurality of intermeshing pinion gears 1247, 1248 rotatably mounted on a carrier member 1249 and disposed in meshing relationship with the ring gear member 1244 and the sun gear member 1242, respectively.

[0219] The planetary gear set 1250 includes a sun gear member 1252, a ring gear member 1254, and a planet carrier assembly member 1256. The planet carrier assembly member 1256 includes a plurality of intermeshing pinion gears 1257, 1258 rotatably mounted

on a carrier member 1259 and disposed in meshing relationship with the ring gear member 1254 and the sun gear member 1252, respectively.

[0220] As a result of the dual clutch arrangement of the invention, the four planetary gear sets 1220, 1230, 1240 and 1250 are divided into first and second transmission subsets 1260, 1261 which are alternatively engaged to provide odd number and even number speed ranges, respectively. Transmission subset 1260 includes planetary gear sets 1220 and 1230, and transmission subset 1261 includes planetary gear sets 1240 and 1250. The output shaft 19 is continuously connected with members of both subsets 1260 and 1261.

[0221] As mentioned above, the first and second input clutches 1262, 1263 are alternatively engaged for transmitting power from the input shaft 17 to transmission subset 1260 or transmission subset 1261. The first and second input clutches 1262, 1263 are controlled electronically, and the disengaged input clutch is gradually engaged while the engaged input clutch is gradually disengaged to facilitate transfer of power from one transmission subset to another. In this manner, shift quality is maintained, as in an automatic transmission, while providing better fuel economy because no torque converter is required, and hydraulics associated with "wet" clutching are eliminated. All gear speeds are preselected within the transmission subsets 1260, 1261 prior to engaging the respective input clutches 1262, 1263. The preselection is achieved by means of electronically controlled synchronizers. As shown, the planetary gear arrangement includes eight torque transmitting mechanisms 1264, 1265, 1266, 1267, 1268, 1269 and 1270. The torque transmitting mechanisms 1268 and 1269 comprise braking synchronizers, and the torque transmitting mechanisms 1264, 1265, 1266, 1267 and 1270 comprise rotating synchronizers.

[0222] Accordingly, the input shaft 17 is alternately connected with the first and second transmission subsets 1260, 1261 (i.e. through the clutch 1262 to the sun gear member 1222 and through the clutch 1263 to the ring gear member 1244). The ring gear member 1224 is continuously connected with the transmission housing 1280. The planet carrier assembly member 1246 is continuously connected with the sun gear member 1232 and the output shaft 19 through the interconnecting member 1272. The sun gear member 1242 is continuously connected with the planet carrier assembly member 1256 through the interconnecting member 1274.

[0223] The sun gear member 1222 is selectively connectable with the ring gear member 1234 through the synchronizer 1264. The sun gear member 1222 is selectively connectable with the planet carrier assembly member 1236 through the synchronizer 1265. The planet carrier assembly member 1226 is selectively connectable with the ring gear member 1234 through the synchronizer 1266. The planet carrier assembly member 1226 is selectively connectable with the planet carrier assembly member 1236 through the synchronizer 1267.

The ring gear member 1254 is selectively connectable with the transmission housing 1280 through the braking synchronizer 1269. The sun gear member 1252 is selectively connectable with the transmission housing 1280 through the braking synchronizer 1269. The planet carrier assembly member 1246 is selectively connectable with the ring gear member 1254 through the synchronizer 1270.

[0224] As shown in Figure 13b, and in particular the truth table disclosed therein, the input clutches and torque transmitting mechanisms are selectively engaged in combinations of three to provide five forward speed ratios and a reverse speed ratio. A sample of the numerical values for the ratios is also provided in the truth table of the Figure 13b. These values are determined utilizing the ring gear/sun gear tooth ratios also given in Figure 13b. The R1/S1 value is the tooth ratio of the planetary gear set 1220; the R2/S2 value is the tooth ratio of the planetary gear set 1230; the R3/S3 value is the tooth ratio of the planetary gear set 1240; and the R4/S4 value is the tooth ratio of the planetary gear set 1250. Also given in Figure 13b is a chart describing the step ratios between the adjacent forward speed ratios and the reverse to first forward speed ratio.

[0225] Those skilled in the art will recognize that the numerical values of the reverse and fifth forward speed ratios are determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 1220, 1230. The numerical value of the first forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 1220. The numerical value of the second forward speed ratio is determined utilizing the ring gear/sun gear tooth ratios of the planetary gear sets 1240, 1250. The numerical value of the third forward speed ratio is 1. The numerical value of the fourth forward speed ratio is determined utilizing the ring gear/sun gear tooth ratio of the planetary gear set 1240.

[0226] While the best modes for carrying out the invention have been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments for practicing the invention within the scope of the appended claims.

Claims

1. A multi-speed transmission comprising:

- an input shaft;
- an output shaft;
- first, second, third and fourth planetary gear sets each having first, second and third members;
- said first member of said first planetary gear set being continuously connected with a stationary member;
- a first interconnecting member continuously in-

- terconnecting said first member of said second planetary gear set with said first member of said third planetary gear set and with said output shaft;
 a second interconnecting member continuously interconnecting a member of said third planetary gear set with said first member of said fourth planetary gear set;
 a first input clutch selectively interconnecting said input shaft with a member of said first or said second planetary gear set;
 a second input clutch selectively interconnecting said input shaft with said second or said third member of said third planetary gear set;
 a first, second, third and fourth torque-transmitting mechanism selectively interconnecting members of said first or second planetary gear sets with other members of said first or second planetary gear sets or with said first input clutch;
 a fifth and sixth torque-transmitting mechanism selectively interconnecting members of said third planetary gear set with members of said fourth planetary gear set;
 a seventh and eighth torque-transmitting mechanism selectively interconnecting members of said fourth planetary gear set with said stationary member; and
 said input clutches and torque-transmitting mechanisms being engaged in combinations of at least three to provide at least six forward speed ratios and a reverse speed ratio.
2. The transmission defined in claim 1, wherein a member of said first planetary gear set is continuously interconnected with a member of said second planetary gear set through a third interconnecting member.
 3. The transmission defined in claim 1, wherein said eight torque-transmitting mechanisms comprise synchronizers.
 4. The transmission defined in claim 1, wherein said seventh and eighth torque-transmitting mechanisms comprise braking synchronizers, and said first, second, third, fourth, fifth and sixth torque-transmitting mechanisms comprise rotating synchronizers.
 5. The transmission defined in claim 1, wherein said first input clutch is applied for odd number speed ranges and said second input clutch is applied for even number speed ranges.
 6. The transmission defined in claim 1, wherein said first input clutch is applied for even number speed ranges and said second input clutch is applied for odd number speed ranges.
 7. The transmission defined in claim 1, wherein said first input clutch and said second input clutch are interchangeable to shift from odd number speed ranges to even number speed ranges, and vice versa.
 8. The transmission defined in claim 1, wherein selected ones of said eight torque-transmitting mechanisms are engaged prior to gear shifting to achieve shifting without torque interruptions.
 9. The transmission defined in claim 3, wherein at least two of said synchronizers comprise a double synchronizer to reduce cost and package size.
 10. A multi-speed transmission comprising:
 - an input shaft;
 - an output shaft;
 - first, second, third and fourth planetary gear sets each having first, second and third members;
 - said first member of said first planetary gear set being continuously connected with a stationary member;
 - a first interconnecting member continuously interconnecting said first member of said second planetary gear set with said first member of said third planetary gear set and with said output shaft;
 - a second interconnecting member continuously interconnecting a member of said third planetary gear set with said first member of said fourth planetary gear set;
 - a first input clutch selectively interconnecting said input shaft with a member of said first or said second planetary gear set;
 - a second input clutch selectively interconnecting said input shaft with said second or said third member of said third planetary gear set;
 - and
 - eight torque-transmitting mechanisms for selectively interconnecting said members of said first, second, third or fourth planetary gear sets with said first or second input clutches, said output shaft, said first or second interconnecting member, said stationary member or with other members of said planetary gear sets, said eight torque-transmitting mechanisms being engaged in combinations of at least three to establish at least six forward speed ratios and a reverse speed ratio between said input shaft and said output shaft.
 11. The transmission defined in claim 10, wherein a member of said first planetary gear set is continu-

- ously interconnected with a member of said second planetary gear set through a third interconnecting member.
12. The transmission defined in claim 10, wherein first, second, third and fourth of said eight torque-transmitting mechanisms are selectively operable for interconnecting members of said first or second planetary gear sets with other members of said first or second planetary gear sets, or with said first input clutch. 5 10
13. The transmission defined in claim 10, wherein fifth and sixth of said eight torque-transmitting mechanisms are selectively operable for interconnecting members of said third planetary gear set with members of said fourth planetary gear set. 15
14. The transmission defined in claim 10, wherein seventh and eighth of said eight torque-transmitting mechanisms are operable for selectively interconnecting members of said fourth planetary gear set with said stationary member. 20
15. The transmission defined in claim 10, wherein planet carrier assembly members of a plurality of said planetary gear sets are of the single pinion type. 25
16. The transmission defined in claim 10, wherein planet carrier assembly members of a plurality of said planetary gear sets are of the double pinion type. 30
17. The transmission defined in claim 10, wherein each of said eight torque-transmitting mechanisms comprises a synchronizer. 35
18. The transmission defined in claim 10, wherein said first input clutch is applied for odd number speed ranges and said second input clutch is applied for even number speed ranges. 40
19. The transmission defined in claim 10, wherein said first input clutch is applied for even number speed ranges and said second input clutch is applied for odd number speed ranges. 45
20. The transmission defined in claim 10, wherein selected ones of said eight torque-transmitting mechanisms are engaged prior to gear shifting to achieve shifting without torque interruptions. 50
21. A multi-speed transmission comprising:
- an input shaft;
 - an output shaft;
 - first, second, third and fourth planetary gear sets each having first, second and third members;
- said first member of said first planetary gear set being continuously connected with a stationary member;
- a first interconnecting member continuously interconnecting said first member of said second planetary gear set with said first member of said third planetary gear set and with said output shaft;
- a second interconnecting member continuously interconnecting a member of said third planetary gear set with said first member of said fourth planetary gear set;
- a first input clutch selectively interconnecting said input shaft with said second or third member of said third planetary gear set;
- a first and second torque-transmitting mechanism selectively interconnecting members of said first and second planetary gear set with said input shaft and, therefore, functioning as second and third input clutches;
- a third and fourth torque-transmitting mechanism selectively interconnecting members of said first or second planetary gear sets with other members of said first or second planetary gear sets, or with said second or third input clutch;
- a fifth and sixth torque-transmitting mechanism selectively interconnecting members of said third planetary gear set with members of said fourth planetary gear set;
- a seventh and eighth torque-transmitting mechanism selectively interconnecting members of said fourth planetary gear set with said stationary member; and
- said input clutches and torque-transmitting mechanisms being engaged in combinations of at least three to provide at least six forward speed ratios and a reverse speed ratio.
22. The transmission defined in claim 21, wherein a member of said first planetary gear set is continuously interconnected with a member of said second planetary gear set through a third interconnecting member.
23. The transmission defined in claim 21, wherein third, fourth, fifth, sixth and seventh of said eight torque-transmitting mechanisms comprise synchronizers.
24. The transmission defined in claim 21, wherein said first input clutch is applied for odd number speed ranges and said second or third input clutch is applied for even number speed ranges.
25. The transmission defined in claim 21, wherein said first input clutch is applied for even number speed ranges and said second or third input clutch is applied for odd number speed ranges. 55

26. The transmission defined in claim 21, wherein said first input clutch and said second or third input clutch are interchangeable to shift from odd number speed ranges to even number speed ranges, and vice versa.
27. The transmission defined in claim 21, wherein selected ones of said eight torque-transmitting mechanisms are engaged prior to gear shifting to achieve shifting without torque interruptions.
28. The transmission defined in claim 21, wherein at least two of said synchronizers comprise a double synchronizer to reduce cost and package size.
29. A multi-speed transmission comprising:
- an input shaft;
 - an output shaft;
 - first, second, third and fourth planetary gear sets each having first, second and third members;
 - said first member of said first planetary gear set being continuously connected with a stationary member;
 - a first interconnecting member continuously interconnecting said first member of said second planetary gear set with said first member of said third planetary gear set and with said output shaft;
 - a second interconnecting member continuously interconnecting a member of said third planetary gear set with said first member of said fourth planetary gear set;
 - a first input clutch selectively interconnecting said input shaft with a member of said first or said second planetary gear set;
 - a second input clutch selectively interconnecting said input shaft with said second or said third member of said third planetary gear set; and
 - seven torque-transmitting mechanisms for selectively interconnecting said members of said first, second, third or fourth planetary gear sets with said first or second input clutch, said output shaft, said first or second interconnecting member, said stationary member or with other members of said planetary gear sets, said seven torque-transmitting mechanisms being engaged in combinations of at least three to establish at least five forward speed ratios and a reverse speed ratio between said input shaft and said output shaft.
30. The transmission defined in claim 29, wherein first, second, third and fourth of said seven torque-transmitting mechanisms are selectively operable for interconnecting members of said first and second planetary gear sets with other member of said first and second planetary gear sets, or with said first input clutch.
31. The transmission defined in claim 29, wherein a fifth of said seven torque-transmitting mechanisms is selectively operable for interconnecting a member of said third planetary gear set with a member of said fourth planetary gear set.
32. The transmission defined in claim 29, wherein sixth and seventh of said seven torque-transmitting mechanisms are operable for selectively interconnecting members of said fourth planetary gear set with said stationary member.
33. The transmission defined in claim 29, wherein planet carrier assembly members of a plurality of said planetary gear sets are of the single pinion type.
34. The transmission defined in claim 29, wherein planet carrier assembly members of a plurality of said planetary gear sets are of the double pinion type.
35. The transmission defined in claim 29, wherein each of said seven torque-transmitting mechanisms comprises a synchronizer.
36. The transmission defined in claim 29, wherein said first input clutch is applied for odd number speed ranges and said second input clutch is applied for even number speed ranges.
37. The transmission defined in claim 29, wherein said first input clutch is applied for even number speed ranges and said second input clutch is applied for odd number speed ranges.
38. The transmission defined in claim 29, wherein selected ones of said seven torque-transmitting mechanisms are engaged prior to gear shifting to achieve shifting without torque interruptions.
39. The transmission defined in claim 29, wherein a member of said first planetary gear set is continuously interconnected with a member of said second planetary gear set through a third interconnecting member.

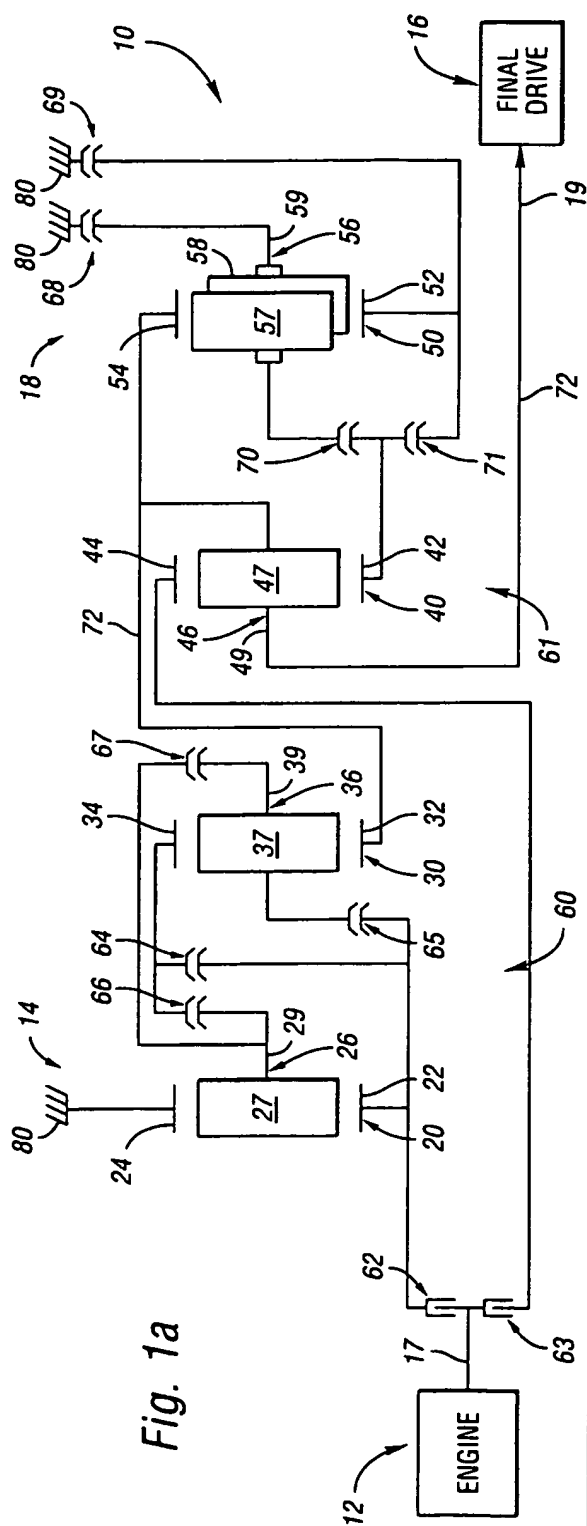


Fig. 1a

	RATIOS	62	63	64	65	66	67	68	69	70	71
REVERSE	-1.96	X		X			X				
NEUTRAL											
1	2.52	X				X					
2	1.42		X				X			X	
3	1	X		X	X						
4	0.70		X						X	X	
5	0.52	X			X	X					
6	0.41		X					X			X

(X = ENGAGED CLUTCH)

Fig. 1b

RATIO SPREAD	6.09
RATIO STEPS	
REV/1	-0.78
1/2	1.77
2/3	1.42
3/4	1.42
4/5	1.34
5/6	1.27

$$\frac{\text{RING GEAR}}{\text{SUN GEAR}}$$

TOOTH RATIO:

$R_1 - 1.50$

$$ZC:1 - \frac{1}{S_1}$$

$R_2 = 1.51$

$$\frac{IC_1 - S_2}{S_2}$$

R3 - 340

$$\frac{S_3}{S_3} = 2.40$$

R4 - 241

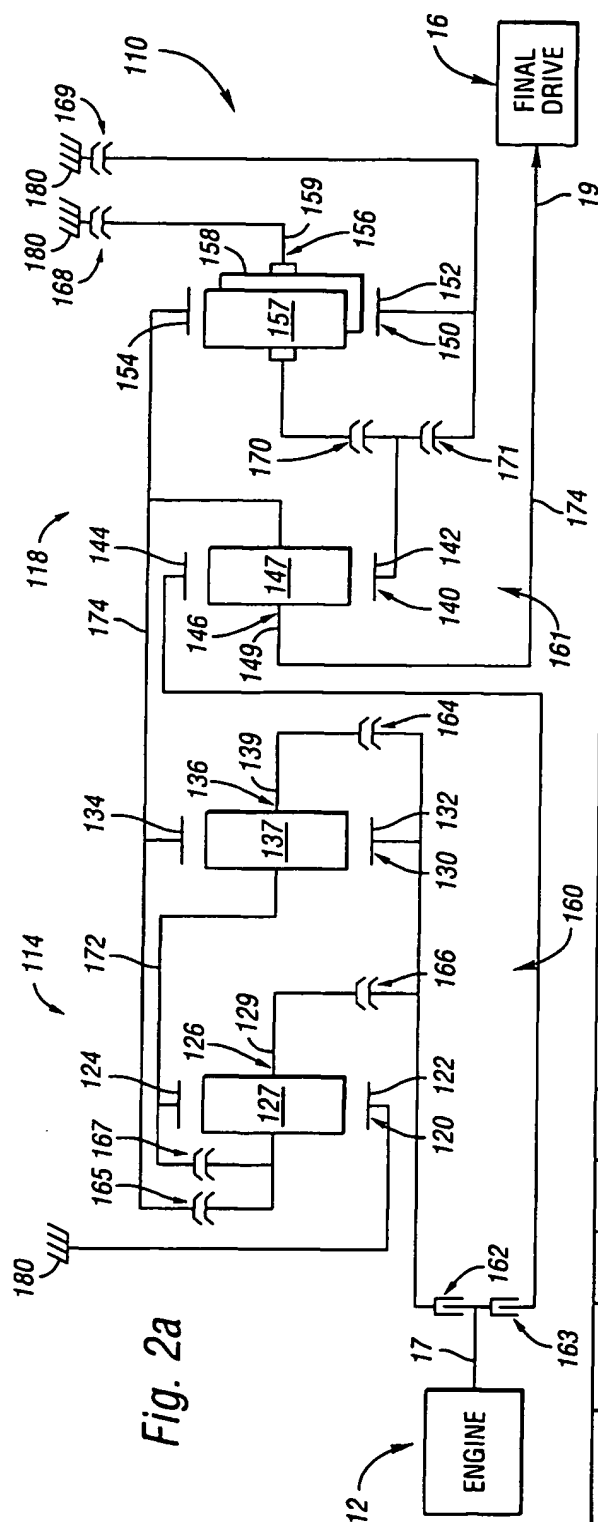


Fig. 2a

	RATIOS	162	163	164	165	166	167	168	169	170	171
REVERSE	-1.52	X					X				
NEUTRAL											
1	2.67	X			X						
2	1.48		X					X		X	
3	1	X		X							
4	0.66		X						X	X	
5	0.48	X				X					
6	0.33		X					X			X

(X = ENGAGED CLUTCH)

(X = ENGAGED CLUTCH)

Fig. 2b

RATIO SPREAD	8.09
RATIO STEPS	
REV/1	-0.57
1/2	1.81
2/3	1.48
3/4	1.51
4/5	1.39
5/6	1.44

$$\frac{\text{RING GEAR}}{\text{SUN GEAR}}$$

TOOTH RATIO:

$$\frac{R_1}{\sigma} = 1.52$$

SI D2

$$\frac{\kappa_2}{S_2} = 1.51$$

R3 - 310

$$\frac{\$3}{\$3} = 1.00$$

$$\frac{R_4}{S_A} = 2.41$$

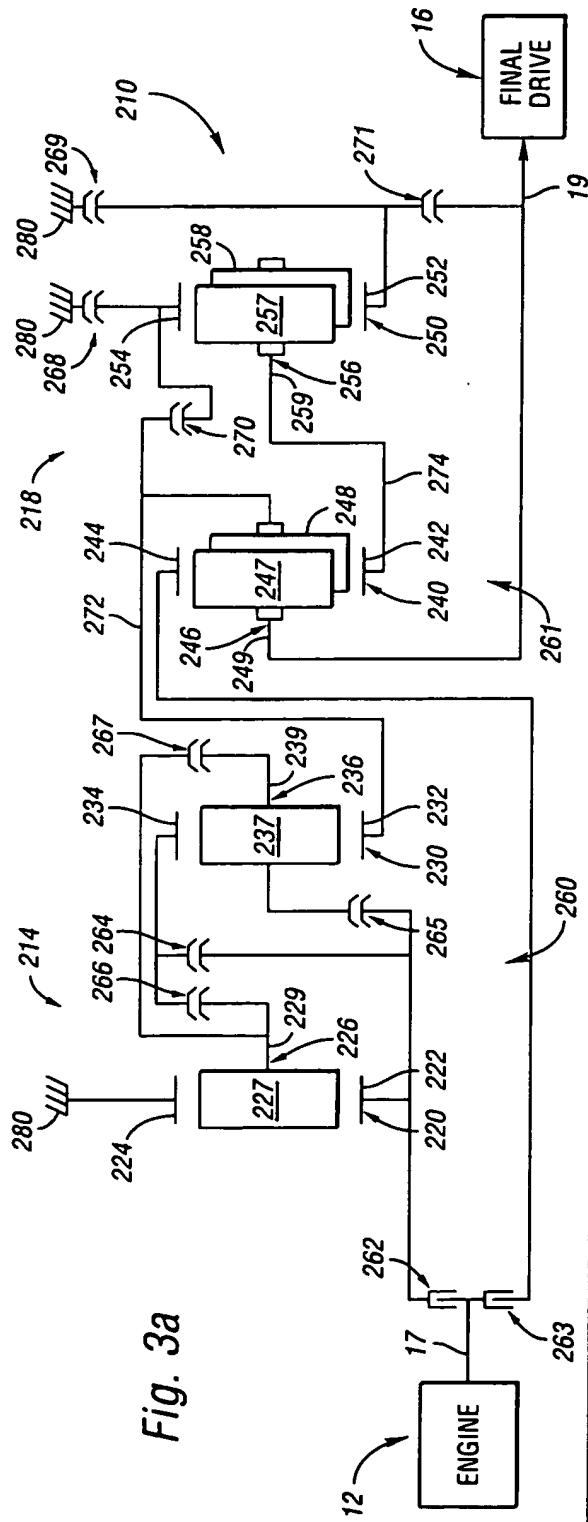


Fig. 3a

	RATIOS	262	263	264	265	266	267	268	269	270	271
REVERSE	-1.46	X		X			X				
NEUTRAL											
1	2.52	X				X	X				
2	1.30		X								
3	1	X		X	X						
4	0.67							X	X		
5	0.48	X			X	X					
6	0.36		X					X			X

(X = ENGAGED CLUTCH)

RING GEAR
SUN GEAR
TOOTH RATIO:

$$\frac{R_1}{S_1} = 1.52$$

$$\frac{R_2}{S_2} = 1.80$$

$$\frac{R_3}{S_3} = 2.99$$

$$\frac{R_4}{S_4} = 2.11$$

RATIO SPREAD	6.89
RATIO STEPS	
REV/1	-0.58
1/2	1.93
2/3	1.30
3/4	1.50
4/5	1.39
5/6	1.31

Fig. 3b

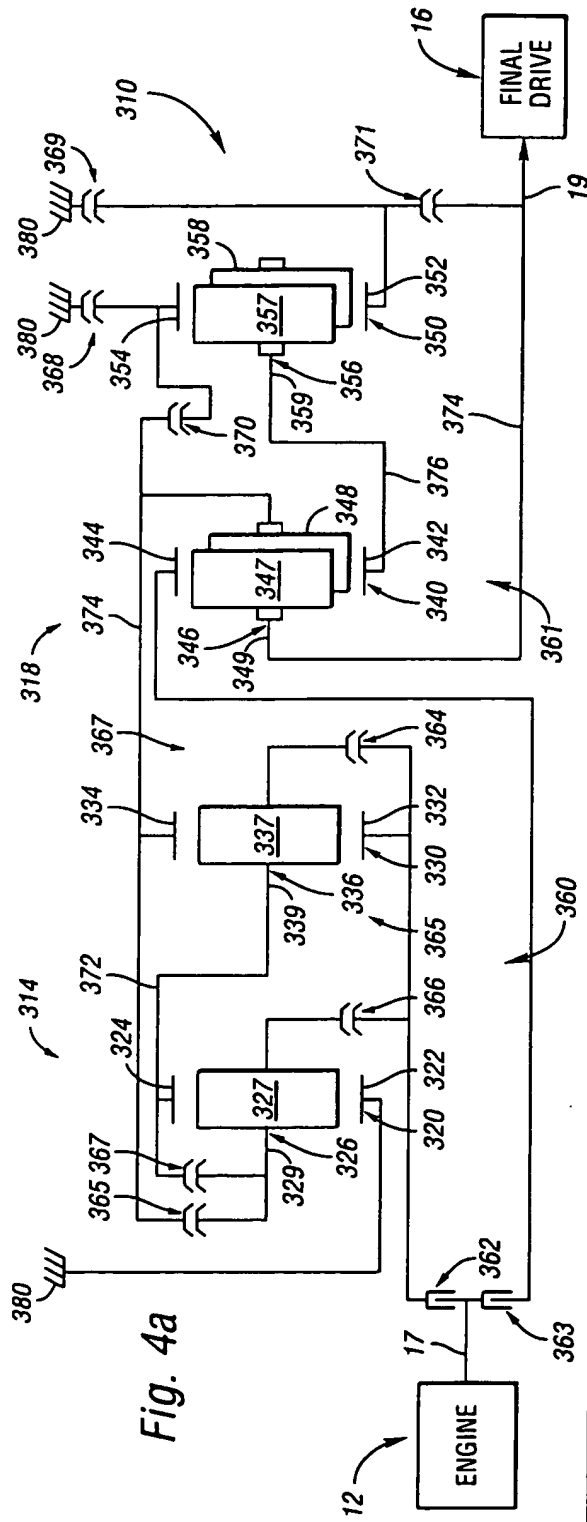


Fig. 4a

	RATIOS	362	363	364	365	366	367	368	369	370	371
REVERSE	-1.52	X					X				
NEUTRAL											
1	2.67	X			X						
2	1.30		X					X	X		
3	1	X		X							
4	0.67		X					X	X		
5	0.48	X				X					
6	0.36		X					X			X

(X = ENGAGED CLUTCH)

RING GEAR
SUN GEAR
TOOTH RATIO:

$$\frac{R_1}{S_1} = 1.52$$

$$\frac{R_2}{S_2} = 1.51$$

$$\frac{R_3}{S_3} = 2.99$$

$$\frac{R_4}{S_4} = 2.11$$

RATIO SPREAD	7.32
RATIO STEPS	
REV/1	-0.57
1/2	2.05
2/3	1.30
3/4	1.50
4/5	1.40
5/6	1.30

Fig. 4b

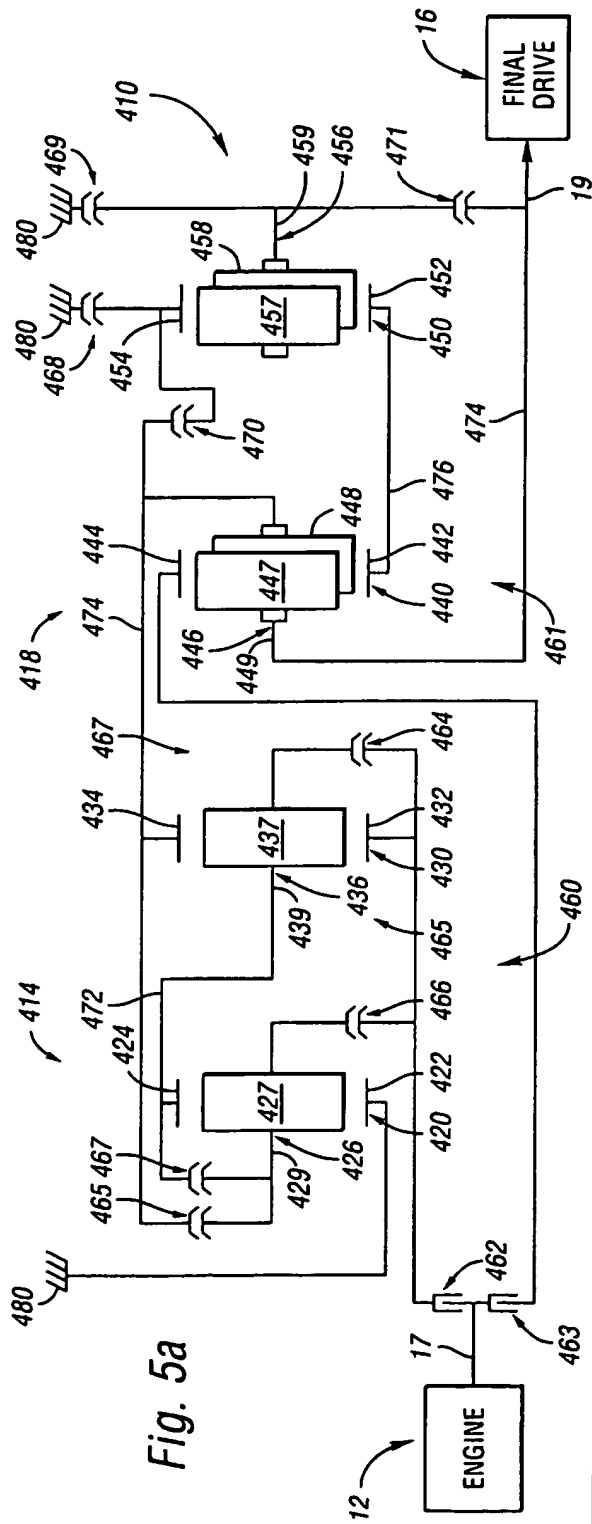


Fig. 5a

	RATIOS	462	463	464	465	466	467	468	469	470	471
REVERSE	-1.52	X					X				
NEUTRAL											
1	2.67	X			X						
2	1.30		X						X		
3	1	X		X							
4	0.63		X					X			
5	0.48	X				X					
6	0.33		X					X			X

(X = ENGAGED CLUTCH)

RING GEAR
SUN GEAR
TOOTH RATIO:

$$\frac{R_1}{S_1} = 1.52$$

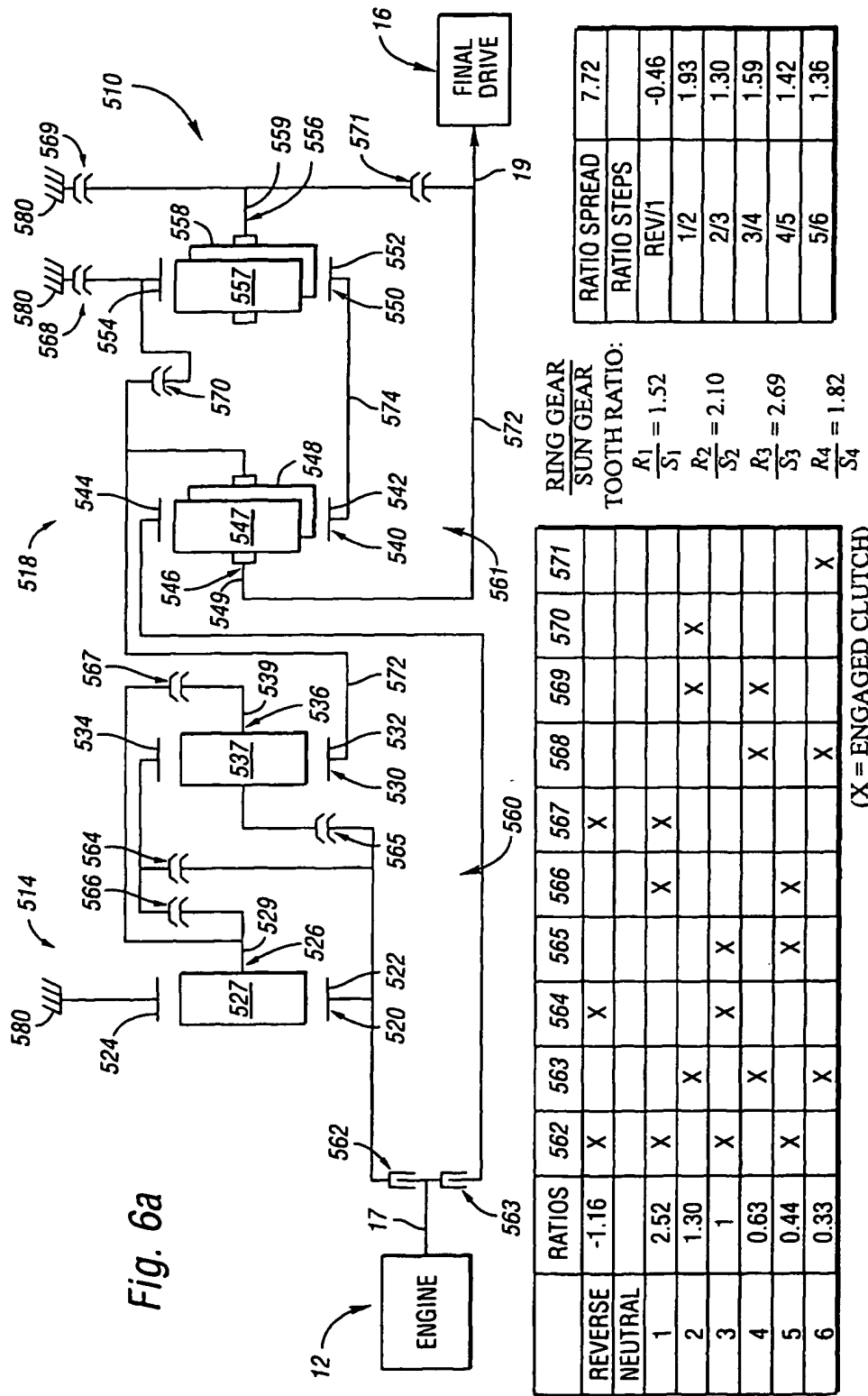
$$\frac{R_2}{S_2} = 1.51$$

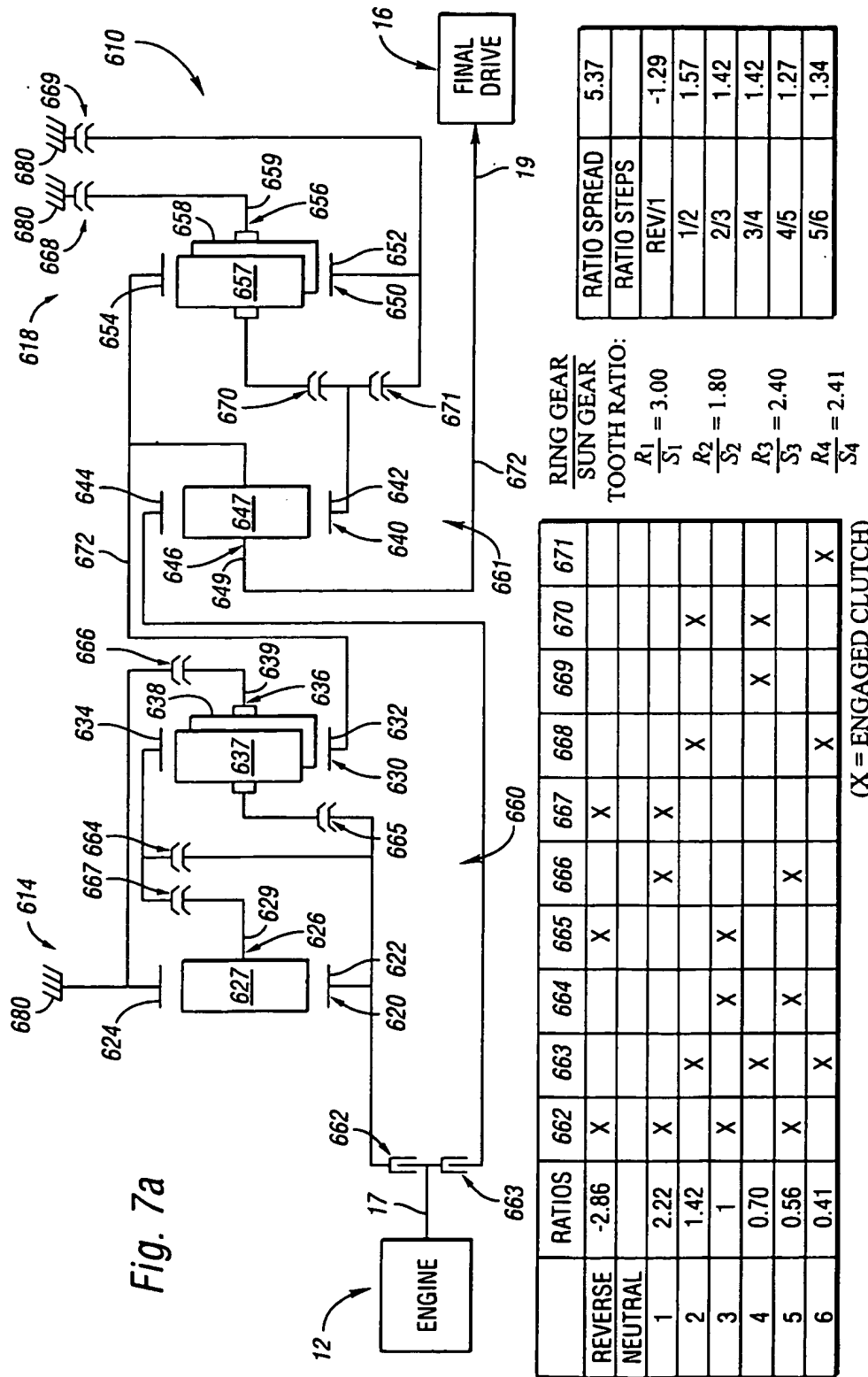
$$\frac{R_3}{S_3} = 2.69$$

$$\frac{R_4}{S_4} = 1.82$$

RATIO SPREAD	8.20
RATIO STEPS	
REV/1	-0.57
1/2	2.05
2/3	1.30
3/4	1.59
4/5	1.32
5/6	1.46

Fig. 5b





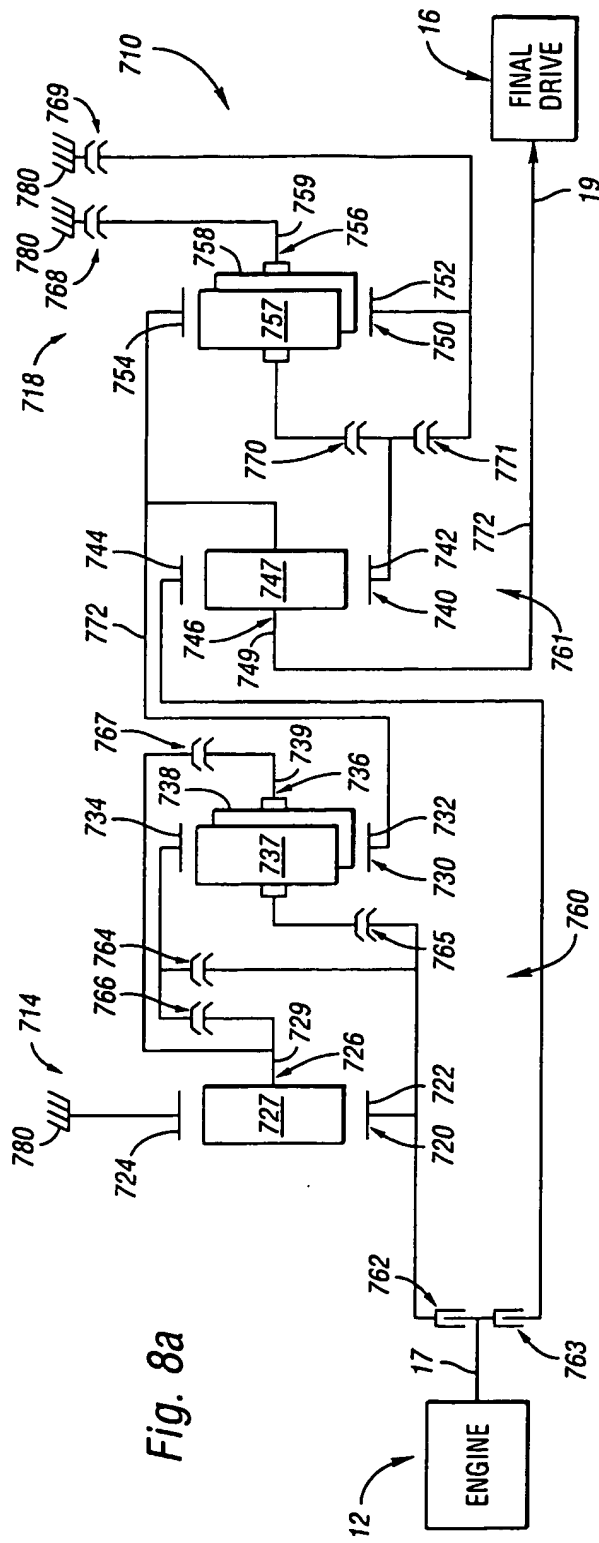


Fig. 8a

	RATIOS	762	763	764	765	766	767	768	769	770	771
REVERSE	-1.85	X			X	X					
NEUTRAL											
1	2.81	X				X	X				
2	1.42		X					X		X	
3	1	X		X	X						
4	0.70		X					X	X		
5	0.53	X		X		X	X				
6	0.41		X				X	X			X

(X = ENGAGED CLUTCH)

RING GEAR
SUN GEAR
TOOTH RATIO:

$$\frac{R_1}{S_1} = 1.81$$

$$\frac{R_2}{S_2} = 2.39$$

$$\frac{R_3}{S_3} = 2.40$$

$$\frac{R_4}{S_4} = 2.41$$

RATIO SPREAD	6.81
RATIO STEPS	
REV/1	-0.66
1/2	1.98
2/3	1.42
3/4	1.42
4/5	1.34
5/6	1.28

Fig. 8b

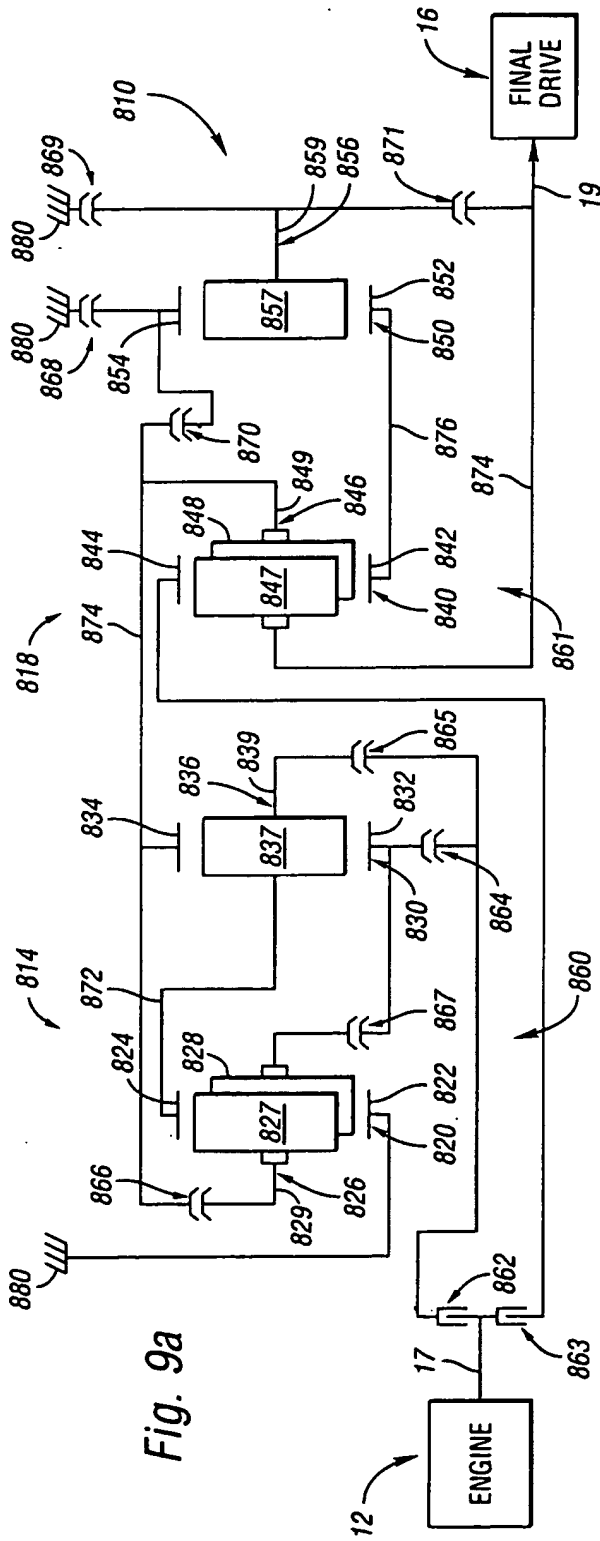


Fig. 9a

	RATIOS	862	863	864	865	866	867	868	869	870	871
REVERSE	-0.90		X						X	X	
NEUTRAL											
1	2.43		X					X			X
2	1.56	X			X	X					
3	1		X				X			X	
4	0.77	X		X							
5	0.52		X					X	X		
6	0.39	X		X		X					

(X = ENGAGED CLUTCH)

RING GEAR
SUN GEAR
TOOTH RATIO:

$$\frac{R_1}{S_1} = 2.11$$

$$\frac{R_2}{S_2} = 1.80$$

$$\frac{R_3}{S_3} = 2.10$$

$$\frac{R_4}{S_4} = 3.00$$

RATIO SPREAD	6.30
RATIO STEPS	
REV/1	-0.37
1/2	1.56
2/3	1.56
3/4	1.29
4/5	1.48
5/6	1.36

Fig. 9b

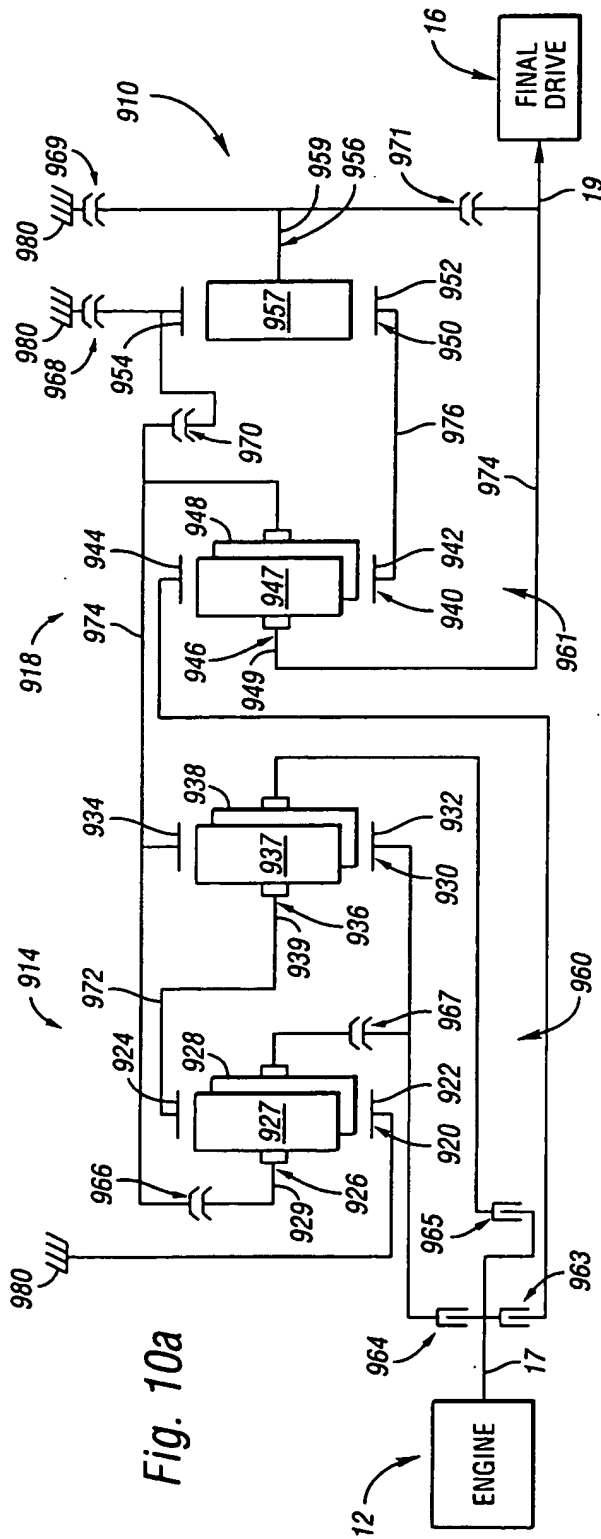


Fig. 10a

	RATIOS	963	964	965	966	967	968	969	970	971
REVERSE	-0.90	X						X	X	
NEUTRAL							X			X
1	2.43	X								
2	1.61		X		X					
3	1	X						X	X	
4	0.63			X		X				
5	0.52	X					X	X		
6	0.44				X	X				

(X = ENGAGED CLUTCH)

RING GEAR
SUN GEAR
TOOTH RATIO:

$$\frac{R_1}{S_1} = 2.11$$

$$\frac{R_2}{S_2} = 1.80$$

$$\frac{R_3}{S_3} = 2.10$$

$$\frac{R_4}{S_4} = 3.00$$

RATIO SPREAD	5.46
RATIO STEPS	
REV/1	-0.37
1/2	1.50
2/3	1.61
3/4	1.59
4/5	1.20
5/6	1.18

Fig. 10b

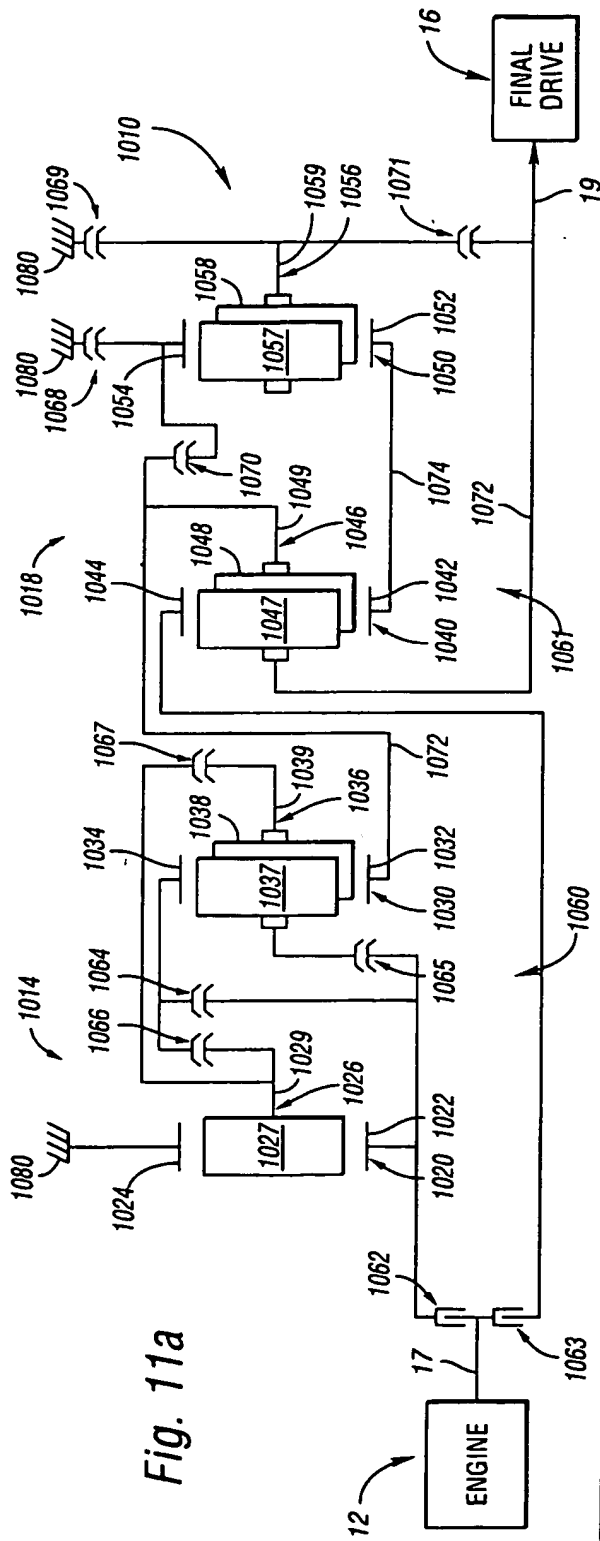


Fig. 11a

	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071
REVERSE	X			X	X					
NEUTRAL										
1	X				X	X				
2		X					X	X		
3	X		X	X						
4		X					X	X		
5	X		X			X				
6		X					X			X

(X = ENGAGED CLUTCH)

RING GEAR
SUN GEAR
TOOTH RATIO:

$$\frac{R_1}{S_1} = 1.52$$

$$\frac{R_2}{S_2} = 2.99$$

$$\frac{R_3}{S_3} = 2.69$$

$$\frac{R_4}{S_4} = 1.82$$

RATIO SPREAD	7.72
RATIO STEPS	
REV/1	-0.50
1/2	1.93
2/3	1.30
3/4	1.59
4/5	1.38
5/6	1.40

Fig. 11b

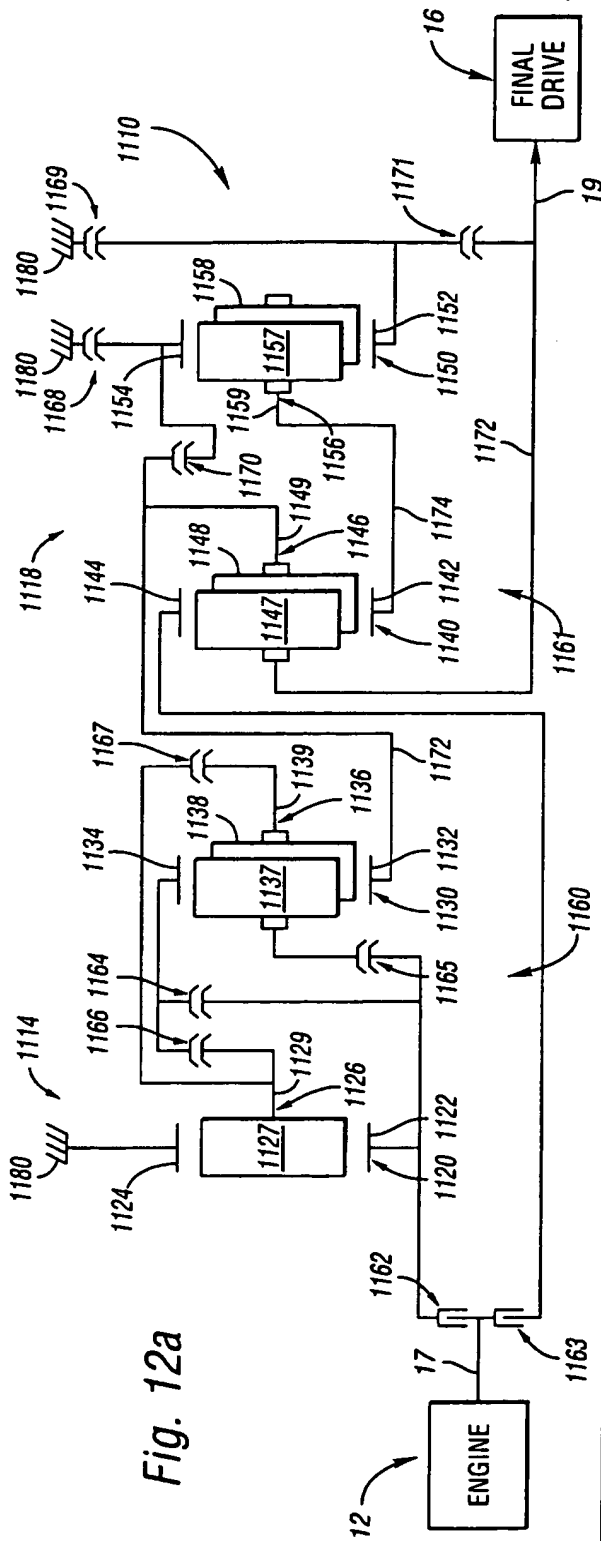


Fig. 12a

	RATIOS	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171
REVERSE	-1.61	X			X	X					
NEUTRAL											
1	2.52	X				X	X				
2	1.30		X					X	X		
3	1	X		X	X						
4	0.67		X	X				X	X		
5	0.50	X		X			X				
6	0.36		X					X			X

(X = ENGAGED CLUTCH)

RING GEAR
SUN GEAR
TOOTH RATIO:

$$\frac{R_1}{S_1} = 1.52$$

$$\frac{R_2}{S_2} = 2.69$$

$$\frac{R_3}{S_3} = 2.99$$

$$\frac{R_4}{S_4} = 2.11$$

RATIO SPREAD	6.89
RATIO STEPS	
REV/1	-0.64
1/2	1.93
2/3	1.30
3/4	1.50
4/5	1.34
5/6	1.36

Fig. 12b

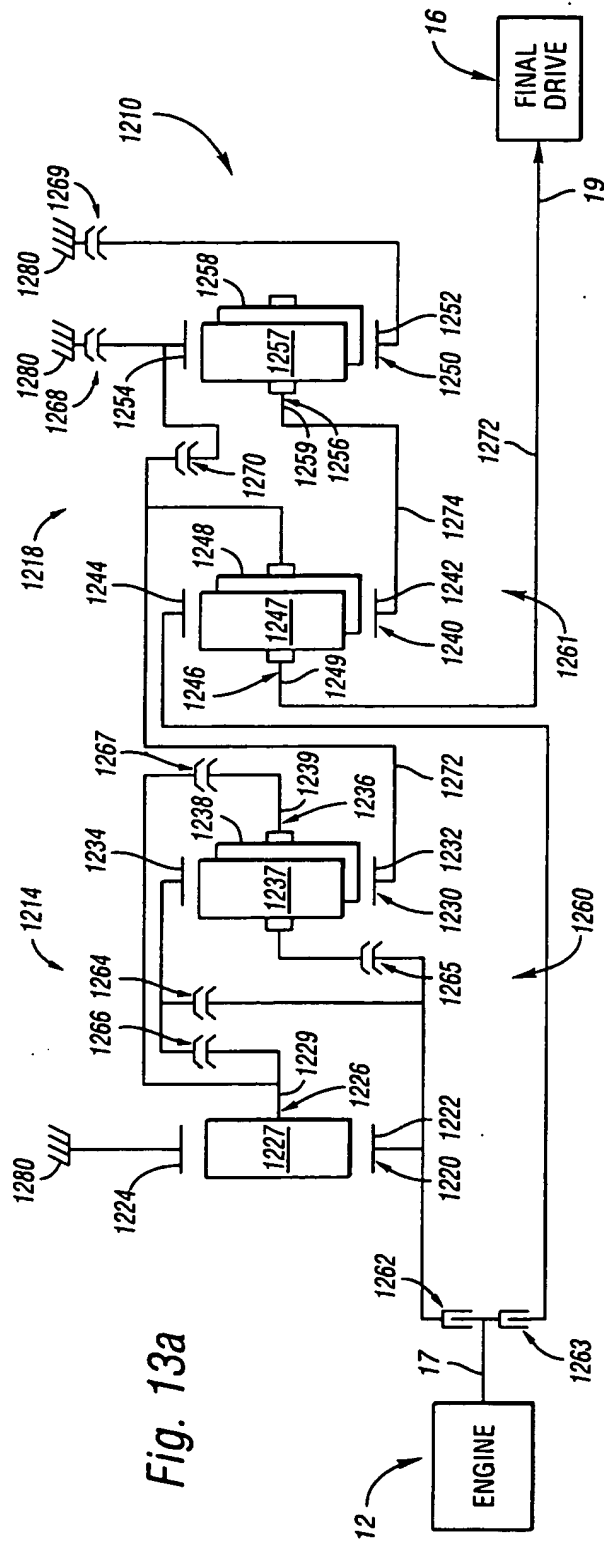


Fig. 13a

	RATIOS	1262	1263	1264	1265	1266	1267	1268	1269	1270
REVERSE	-1.61	X			X	X				
NEUTRAL										
1	2.52	X				X	X			
2	1.30		X						X	X
3	1	X		X	X					
4	0.67		X					X	X	
5	0.50	X		X			X			

(X = ENGAGED CLUTCH)

Fig. 13b

RATIO SPREAD	5.04
RATIO STEPS	
REV/1	-0.64
1/2	1.93
2/3	1.30
3/4	1.50
4/5	1.34

$$\frac{\text{RING GEAR}}{\text{SUN GEAR}}$$

TOOTH RATIO:

$$\frac{R_1}{C_1} = 1.52$$

R2 - 360

$$\frac{S_2}{S_1} = 2.09$$

$$\frac{V_3}{S_3} = 2.99$$

$$\frac{R_4}{S_A} = 2.11$$